S
363.738 Montana general
A7mgac agricultural
1994 chemical ground
water management
plan

Montana
General Agricultural Chemical Ground Water Management Plan

STATE DOCUMENTS COLLECTION

SEP - 7 1994

MONTANA STATE LIBRARY
1515 E. 6th AVE.
HELENA, MONTANA 59620

Strategies To Protect Ground Water From Agricultural Chemicals Through Education And Information

Technical Document 94-01

MONTANA STATE UNIVERSITY
1893•CENTENNIAL•1993
Extension Service

PLEASE RETURN

MONTANA STATE LIBRARY
S 363.738 A7mgac 1994 c.1
Montana general agricultural chemical gr
3 0864 00089843 0

Table of Contents

PLEASE RETURN

Authors 2

Foreword 3

Preface 4

Technical Committee 4

Policy and Management Committee 5

1. Introduction 6

2. Montana's Ground Water and Physiography

Ground Water and Geology 8
Geographic Occurrence of Ground Water in Montana 9
Statewide Ground Water Use 13

3. Factors Contributing to Agricultural Chemicals in Ground Water

Pesticide Residues and Nutrients in Ground Water and Surface Water Environments 16
Sources of Impairment 16
Aquifer Sensitivity/Vulnerability 17
Some Factors Which Contribute To Aquifer Vulnerability Assessment 18
Pesticides 20
Plant Nutrients 24
Factors That Make a Plant Nutrient Leachable 28

4. Human Health, the Environment and Agriculture

Classification of Ground Water and Surface Water in Montana 31
Pesticide Residues and Nutrients 31

5. Monitoring

Ambient Monitoring 35
Follow-up Monitoring 36
Compliance Monitoring 36
Quality Assurance/Quality Control 37
Monitoring Results 37

6. Sampling and Analysis

Impairment Sampling 39
Sample Analysis 41

7. Best Management Practices and Plans to Protect Ground Water

Protection of Montana's Ground Water Resources 46
Best Management Practices 47
Best Management Practice Summaries 55

8. Montana Agricultural Chemical Ground Water Protection Act and Related Laws

The Montana Agricultural Chemical Ground Water Protection Act 59
Montana Pesticide Act 63
Federal Insecticide, Fungicide and Rodenticide Act 64
Remediation of Contaminated Areas 67
Related Regulations for Pesticides and Fertilizers 68

9. Roles of Agencies

Agencies Involved in Education, Research, Data Collection, Compliance, and Enforcement 71
Sources of Information 76

10. If My Water Is Impaired What Do I Do? . . 78

Additional References 80

List of Figures and Tables 85

Appendix A

Directors of State and Federal Agencies in Montana with ground water responsibilities 86

Appendix B

State of Montana MSU Extension Offices 86

Appendix C

State Analytical Laboratories 87

Appendix D

State of Montana County Sanitarian Offices 87

Acronyms 90

Glossary 91

Authors

General Management Plan Co-Chairs

George Algard

Montana Department
of Agriculture

Jeff Jacobsen

Montana State University
Extension Service

General Management Plan Coordinator

Heidi Hart

Montana State University
Extension Service

Development and Implementation Committee

Jay Sinnott

Environmental Protection
Agency

Kate Miller

Montana Bureau
of Mines and Geology

Steve Baril

Rocky Lundy

Donna Rise

Montana Department
of Agriculture

Carolyn DeMartino

Montana Department of
Health and Environmental
Sciences

Kirk Waren

Montana Department
of Natural Resources
and Conservation

Phil Johnson

Montana Department
of Transportation

Debbie Kaiser

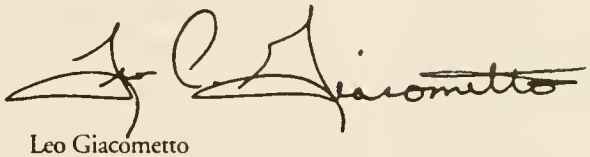
Soil Conservation Service

Bob Davis

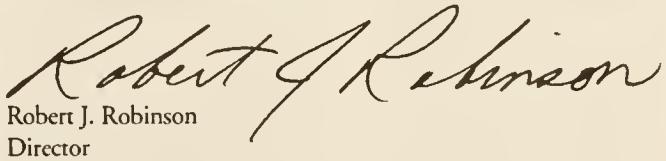
United States Geological
Survey

Foreword

This General State Agricultural Chemical Ground Water Management Plan (GMP) includes general program elements as outlined in the *Montana Agricultural Chemical Ground Water Protection Act (MACGWPA)*. The MACGWPA *Administrative Rules of Montana* provides the authority for the development and implementation of the GMP and the authority to enforce specific management plans. The document discusses the elements that the state of Montana believes to be important in the protection of ground water from impairment by agricultural chemicals. It includes a discussion of current best management practices (BMPs) for the use of pesticides and fertilizers (nutrients). It also includes discussions of Montana's ground water resources, monitoring and sampling procedures, health standards, and the various laws and rules applicable to ground water in Montana. The GMP is not enforceable, but will be dynamic and reflect changes in BMPs and other technologies as they change over time. The GMP will serve as a guide for the preparation of specific management plans when conditions require their development as required by the MACGWPA.



Leo Giacometto
Director
Montana Department of Agriculture



Robert J. Robinson
Director
Montana Department of Health and Environmental Sciences

Dr. Andrea L. Pagenkopf
Vice Provost for Outreach and
Director Montana State University Extension Service

Preface

This General Management Plan (GMP) is funded from the Montana Agricultural Chemical Ground Water Protection Act (MACGWPA). The GMP is initiated by the Montana Department of Agriculture (MDA) and the Montana State University Extension Service (MSUES) in cooperation with other agencies. The GMP provides guidance for the prudent use of fertilizers (and other nutrient sources), pesticides, and the protection of ground water resources. The GMP also identifies Best Management Practices (BMPs) designed to reduce nutrient and pesticide impairment of Montana's water resources and to protect present and future beneficial uses of ground water. A unique set of BMPs should be applied to match the diverse conditions present in farm fields. The intent is to provide information on the activities and programs of the State designed to protect ground water from nutrient and pesticide impairment. The GMP provides agricultural chemical users and the public, information and landowner actions needed to protect ground water.

A Development and Implementation Committee was formed with personnel from various agencies. The goal of the committee was to prepare a Technical Report containing a General Management Plan and recommended nutrient and pesticide best management practices for Montana agriculture. A Technical Committee was selected by the agencies and groups involved to review the document to ensure that the various laws, rules and other technical aspects were adequately addressed. A Policy and Management Committee, representing the agencies and groups potentially affected by this document, served as a final review team. As required by the MACGWPA (80-15-211, MCA), the document was reviewed by the Montana Department of Health and Environmental Sciences. The report is intended to provide federal, state and county agency staff and agricultural producers with a comprehensive discussion of agricultural management practices and procedures for maintaining and protecting surface and ground water quality in Montana. Fertilizer and Pesticide Best Management Plan *Fact Sheets* based on this GMP are being developed by the MSUES and the MDA. The Fact Sheet Series are intended for use by user groups, fertilizer and pesticide applicators, and the general public. Fact Sheets will be available through the MSUES county offices and the MDA.

Technical Committee

John Arrigo
Montana Department of Health and Environmental Sciences

Kirk Waren
Montana Department of Natural Resources and Conservation

Tom Hughes
Montana Department of State Lands

Terry Yarger
Montana Department of Highways

Nancy Hinman
University of Montana

Steve Custer
Montana State University

Jeff Jacobsen
Montana State University Extension Service

George Algard
Montana Department of Agriculture

Kate Miller
Montana Bureau of Mines and Geology

Paul Sihler
Environmental Quality Council

Glenn Phillips
Department of Fish Wildlife and Parks

Allan Cox
Montana State Library

Bill Inskeep
Montana State University

Bob Davis
United States Geological Survey

Debbie Kaiser
Soil Conservation Service

Gene Surber
Montana Association of County Extension Agents

Doug Kikkert
Montana Environmental Health Association

Peter Rice
University of Montana

Dale Harms
United States Fish and Wildlife Service

Jay Sinnott
United States Environmental Protection Agency

Ron Follett
United States Department of Agriculture

Jane Holzer
Montana Salinity Association

Pam Langley
Montana Agricultural Business Association

Jo Brunner
Montana Water Resources Association

Nancy Matheson
Alternative Energy Resources Organization

Jeff Lucero
Bureau of Land Reclamation

Laszlo Torma
Montana State University

Policy and Management Committee

Gary Gingery
Montana Department of Agriculture

Don Vidrine
Montana Department of Health and Environmental Sciences

Marvin Miller
Montana Bureau of Mines and Geology

Greg Ames
Montana Department of Natural Resources and Conservation

Jeff Hagener
Montana Department of State Lands

Edrie Vinson
Montana Department of Highways

Don Mathre
Montana State University

Scott Hoag
United States Department of Agriculture

Dan Fraser
Montana Department of Health and Environmental Sciences

Terry Claver
Intermountain Roundwood Association

Wayne Van Voast
Montana Bureau of Mines and Geology

Deborah Schmidt
Environmental Quality Council

Glenn Phillips
Montana Department of Fish Wildlife and Parks

Jim Stimson
Montana State Library

Joe Moreland
United States Geological Survey

Eric Finke
United States Environmental Protection Agency

Kris Aase
United States Department of Agriculture

Tom Bozorth
Bureau of Land Management

Bob Delk
Bureau of Indian Affairs

Gene Surber
Montana County Extension Agents

Pam Langley
Montana Agricultural Business Association

Jane Barry
Montana Association of Nurserymen

Jake Cummins
Montana Farm Bureau

Randy Johnson
Montana Grain Growers Association

Jess Kilgore
Montana Stockgrowers Association

Tom Parks
Montana Bureau of Reclamation

Allen Rustad
Montana Association of County Officials

Dale Harms
United States Fish, Wildlife and Parks

Doug Kikkert
Montana Environmental Health Association

Al Kurki
Alternative Energy Resources Organization

Ted Doney
Montana Dairyman's Association

Peggy Trenk
Western Environmental Trade Association

Jane Holzer
Montana Salinity Association

Jo Brunner
Montana Water Resources

Dave Burch
Montana Weed Control Association

George Snider
Montana Grain Elevators Association

Mary Schuler
Women Involved in Farm Economics

Bob Racine
Blackfeet Agency

Debi Madison
Fort Peck Agency

Monte Mlekush
Northern Plains Resource Council

Ray Beck
Montana Department of Natural Resources and Conservation

Dennis Olson
Northern Plains Resource Council

Jason Whiteman
Northern Cheyenne Indian Reservation

Clayton Matt
Confederated Salish and Kootenai Tribes

CHAPTER 1
INTRODUCTION

Montana is ranked *second* in the nation for total acres of land in farms and ranches. Montana also ranks in the nation's top five in several livestock and crop production categories; including beef cattle, sheep, wheat, barley, and oats. In addition, Montana plays an important role in the production of such alternative crops as canola, safflower, and mint. The state also produces alfalfa, other forages, and potato seed. In numerous regions of Montana, weather conditions allow for the growing of fruits such as apples and sweet cherries (MDA, 1992).

The use of pesticides and fertilizers in Montana is as diverse as its agriculture. Of the total land (93 million acres) in Montana, two thirds (60.5 million acres) is in farms and ranches. Of that 60.5 million acres, 30 percent (18 million acres) is cropland. Of these 18 million acres in crop production (Figure 1.1), the majority (7.5 million acres) is in small grains production (wheat, barley, oats) (Figure 1.2). The remainder of the land is in summer fallow, hay, corn, sugarbeets, and alternative or specialty crops.

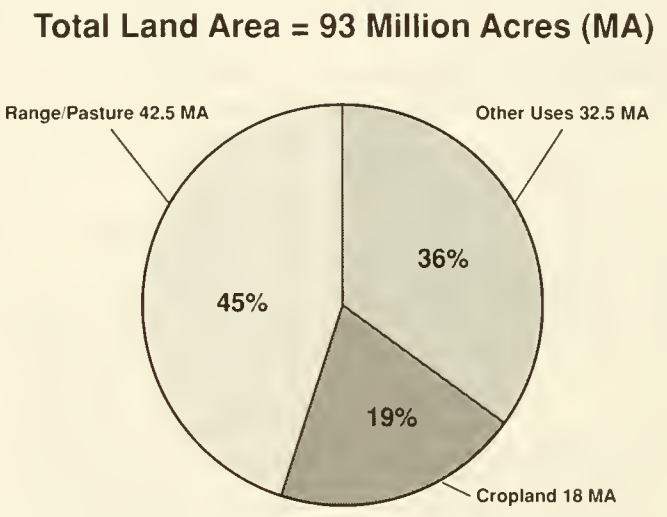


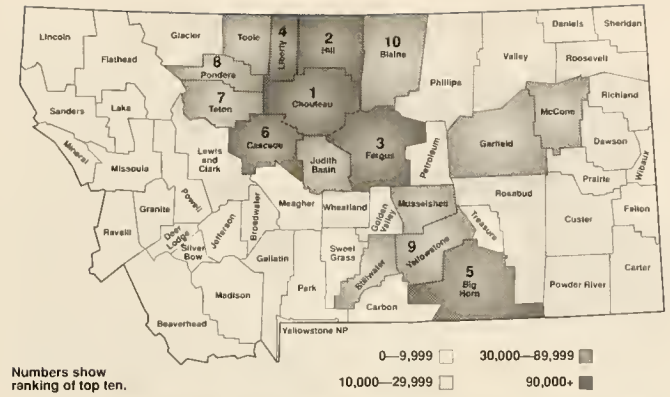
FIGURE 1.1. Montana land use (MDA et al., 1992).

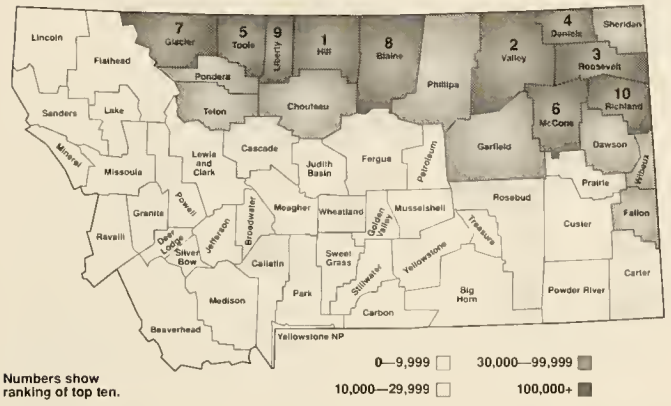
Montana relies heavily on water resources for agriculture, recreation and human consumption. Ground water is an important source of this supply. Ground water supplies *over half* of the state's drinking water. In rural areas, ground water accounts for 95% of the water consumed. Agriculture, as an industry, is dependent on ground water for irrigation and stock water. Many of the streams and several of the state's cold-water fish hatcheries also rely heavily on ground warer. All of these uses make Montana's ground water a vitally important resource.

Public concern for potential impairment of water resources by agricultural chemicals (pesticides and fertilizers) has increased in recent years. Pesticides are used to control any undesirable form of plant or animal life (i.e., fungicides, herbicides, insecticides, and rodenticides). Fertilizers improve crop growth and quality. Surface water (lakes, streams, rivers, and ponds) and ground water (which occurs in saturated soil and bedrock below the water table) are subject to impairment from many sources including septic systems, leachate from landfills, improper disposal and storage of hazardous and household waste, leaking underground pipes and tanks, oil drilling, mining, post and pole operations, and agricultural practices. Although each of these are important potential impairment sources, this document will only address the *potential impairment from agricultural chemicals.* It is essential that all users of fertilizers and pesticides understand their unique properties and interactions in the plant-soil-water environment in order to protect water resources.

The *Montana Agricultural Chemical Ground Water Protection Act (80-15-101-414, MCA)* became effective January 1, 1990. The MACGWPA assigned specific responsibilities to the Montana Department of Health and Environmental Sciences (MDHES), the Montana Department of Agriculture (MDA), and the Montana State University Extension Service (MSUES). The Act directs these agencies to:

1. protect ground water and the environment from impairment or degradation due to the use of agricultural chemicals;
2. allow for the proper and correct use of agricultural chemicals;
3. provide for the management of agricultural chemicals to prevent, minimize and mitigate their presence in ground water; and





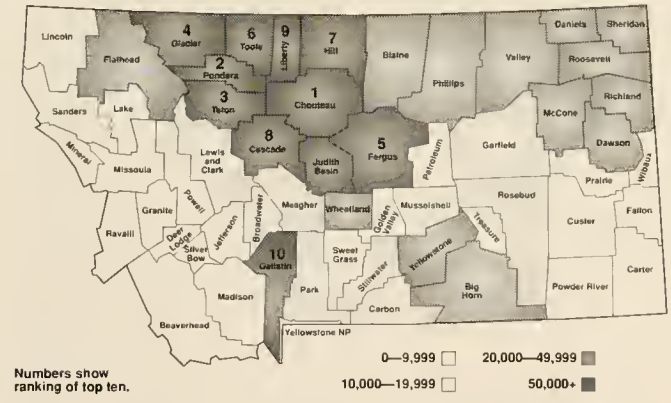


FIGURE 1.2. Montana's top ten counties in harvested acreages of winter wheat, spring wheat and barley (MDA et al., 1992).

4. provide for education and training of agricultural chemical applicators and the general public on ground water protection, agricultural chemical use, and the use of alternative practices.

To achieve these policies, the Act directs the Montana Department of Agriculture to develop and implement a *general state agricultural chemical ground water management plan (GMP)*. This document provides information on the twelve program elements that together form the basis of the GMP. The twelve elements that are described and/or discussed include:

1. State's philosophy and goals toward protecting ground water;
2. Roles and responsibilities of state agencies;
3. Legal authority;
4. Resources;
5. Basis for assessment and planning;
6. Monitoring;
7. Prevention actions;
8. Response to detections of pesticides;
9. Enforcement mechanisms;
10. Public awareness and participation;
11. Information dissemination; and
12. Records and reporting.

Agricultural chemicals are tools for agriculture in Montana. The decision to apply an agricultural chemical requires the implementation of all current technologies and careful consideration of environmental implications. Prudent use of agricultural chemicals in conjunction with proper tillage systems, cover crops, erosion control measures, animal stocking rates, and related agricultural practices will *maintain the integrity* of Montana ground water and surface water resources.

Cited References

Montana Department of Agriculture et al. 1971-1992. Montana agricultural statistics. Montana Department of Agriculture and Montana Crop and Livestock Reporting Service, Helena, MT.

Chapter 2
Montana's Ground Water and Physiography

Ground Water and Geology

Availability of ground water is closely linked to geology and is influenced by both regional and local geological conditions. The term **geology** is usually associated with the rock, the nature of the deformation of the rock in the area, and the sediment (the soil) above the rock which forms surficial deposits. The rock is generally hard and consolidated, while the sediment is composed of weathered and broken unconsolidated material. Ground water fills the open spaces in rock and sediment. Such open spaces are called *voids* or *pore spaces*. Voids or pore spaces exist between soil particles, in the spaces between the grains of sand and gravel, cracks in solid rocks, and solution cavities in carbonate rocks (such as limestone).

Two terms of great importance in ground water geology are **porosity** and **permeability**. Porosity is a measure of the voids in a material (rock, gravel, sand, or clay). Permeability is a measure of the material's ability to transmit water. In general, the greater the porosity and the larger the pores or voids, the greater the permeability. However, a rock may be highly porous, but ground water will only move slowly through it if the pore spaces are extremely small. For example, shale and clay may contain as much water as half their total volume. Yet, the water will not flow through these materials at any appreciable rate.

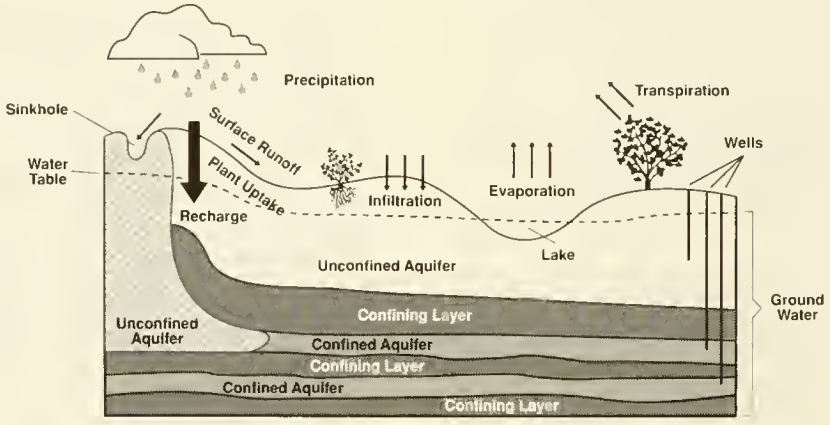
Most ground water comes from precipitation that falls on the ground and percolates below the soil. Unlike surface water, however, the amount of ground water in an underground reservoir does not depend on a single year's precipitation, but on the total recharge over many years.

Ground and surface water are in motion and are a part of the hydrologic cycle (Figure 2.1). Water evaporates from the sea; then, due to atmospheric air masses, it moves over the earth and falls back to the surface as rain or snow. Of that precipitation falling on land: some returns to the atmosphere by direct evaporation from the soil surface, lake, stream, reservoir surfaces; and by transpiration (water vapor emitted by plants during growth); some returns to the seas as runoff and some percolates below the surface to become part of the ground water reservoir (Groff, 1958).

Water that has migrated downward due to gravity to the **zone of saturation** below the water table, where all the voids are filled, is distinguished from the unsaturated zone where all the pores are not filled. The unsaturated zone is above the saturated zone and is also called the **zone of aeration** or **vadose zone**. Movement through this zone is controlled by molecular or capillary forces. Water in the saturated zone is ground water, which does not include the soil, vadose or gravitational water above the water table. An **aquifer** is a water-bearing formation that transmits water in sufficient quantity to supply wells or springs. Aquifers may be classified as **unconfined** or **confined** depending upon how it occurs.

An unconfined aquifer occurs beneath the water table in unconsolidated materials (gravels, sands and clays,) and sometimes in bedrock. Normally, shallow ground water moves slowly and flows in the direction that the land slopes. The water table roughly parallels the land surface, but is typically a little deeper on hill tops and a little shallower in valley bottoms. The water occasionally may intersect the land surface in valleys and depressions. When it does, ground water may discharge as a spring, or into a swamp, pond, or stream.

FIGURE 2.1. Water movement on the land surface and in the soil (Miller, 1993).



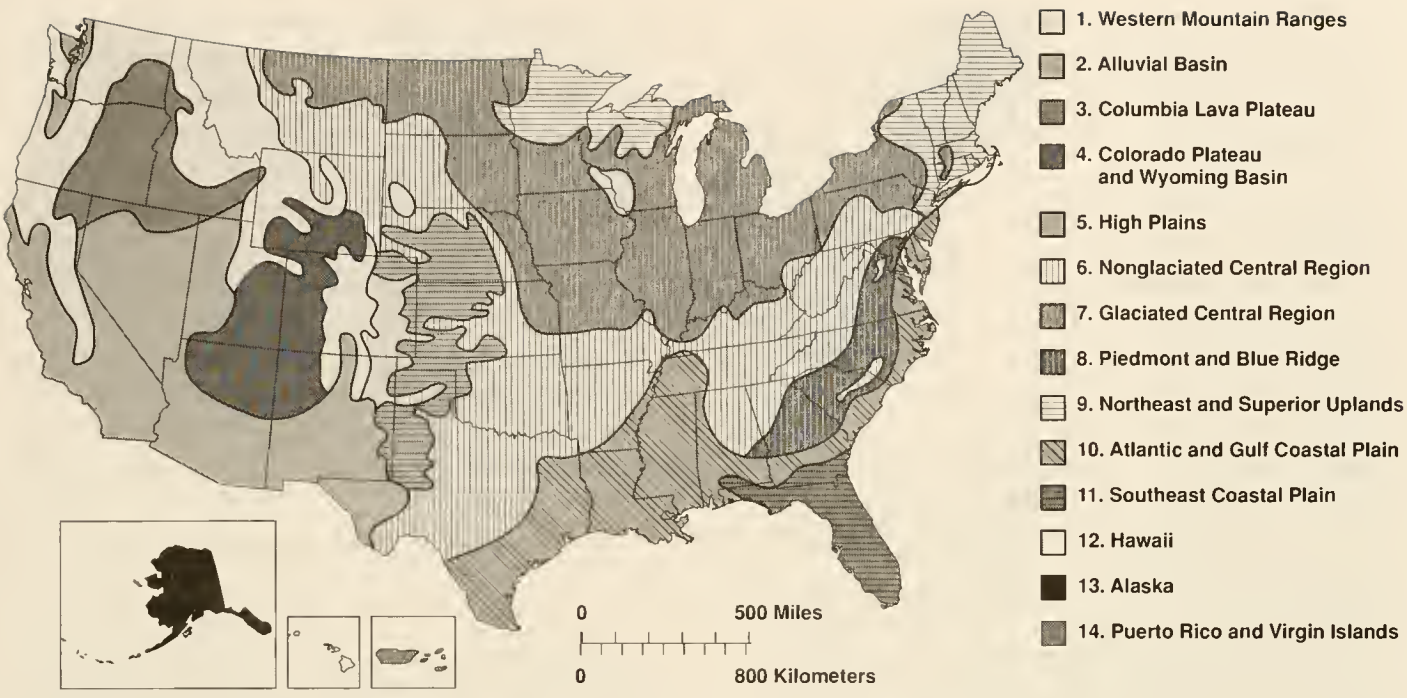


FIGURE 2.2. Ground water regions of the United States (Modified from Heath, 1983).

Confined aquifers are permeable beds lying between slowly impermeable beds or **aquitards** (more commonly called "confining layer"). The aquitard holds the water in the aquifer under pressure. When a well taps into a confined aquifer and the water in the well rises above the top of the aquifer it is called an **artesian well**; the water may or may not flow at the surface. An artesian aquifer is often supplied by infiltration from precipitation in the recharge area which may be many miles distant from the well site. The movement of water from the recharge area to the discharge location may require days or centuries.

Geographic Occurrence of Ground Water in Montana

Heath (1983) subdivided the nation into ground water provinces (Figure 2.2). In Montana, there are three provinces (Western Mountain Ranges, Nonglaciated Central Plains, and Glaciated Central Region). Each region is characterized by certain conditions of topography, climate, geology, and ground water.

The Western Mountain Ranges encompass the mountainous areas of the northwestern, western and southwestern parts of Montana. The Nonglaciated Central Region in Montana contains isolated mountain ranges in central Montana (west of the Judith, Big Snowy, and Crazy Mountains), and the more subdued topography of the region most people think of when discussing the Great Plains. The Glaciated Central Region is similar to the Nonglaciated Central Region, but is covered by a veneer of glacial deposits. Groff (1958) divided the state slightly different to better distinguish the western mountains from the central plains and mountains, and the eastern plains (Figure 2.3). To highlight local recharge in the folded and faulted isolated mountains of the Central Region, the divisions of (Groff, 1958) will be adopted for discussion, but one must remember the glacial veneer. This glacial veneer which generally occurs north of the Missouri River influences the behavior of shallow ground water in both the Central and Eastern regions (Compare Figure 2.2 and 2.3).

Western Montana

Physiography and Climate

The Western Geographic Division (Figure 2.3) includes that part of Montana which is west and south of the *eastern front* of the Rocky Mountains. The Continental Divide lies completely within this division. This division includes all of Montana west of the Little Belt Mountains, Pryor Range, Bighorn Range, Bridger Range, and Beartooth-Absaroka Range. Western Montana is characterized by rugged mountain ranges that form a part of the Rocky Mountain System. Valleys separate the mountains and delineate the irregular pattern of the headwaters of the Columbia and Missouri rivers. Elevations of the mountains range from 6,000 to over 12,000 feet; whereas, the elevations of the valleys range from less than 2,000 feet to more than 5,000 feet. This wide range of elevation has a profound effect on the climate of the region which may be semi-arid in the valleys (10-15 inches of annual precipitation) and humid in the high mountains (as much as 100 inches of annual precipitation). The overall average annual precipitation in western Montana is considerably higher than in the central and eastern portions of the State. The valleys contain a small amount of irrigated land relative to the total area of the region. The adjoining mountain areas form the collection and storage areas for surface water essential to irrigated agriculture.

FIGURE 2.3. The State of Montana divided into three divisions each characterized by certain conditions of topography, climate and geology (Groff, 1958).

Bedrock Geology

The bedrock of western Montana consists of Precambrian, Paleozoic, and Mesozoic sedimentary rocks. In the northern part of the Western Province (north of Helena) the dominant rocks at the surface are Precambrian sedimentary rocks that have been altered by heat and pressure which has eliminated much porosity and permeability. This northern part of the Western Province does contain some younger faulted sedimentary rocks on the Eastern range front which may provide ground-water recharge to the Central Province. In the southern part of the Western province, the bedrock exposed at the surface consists of a heterogeneous system of sedimentary rocks. These include Paleozoic and Mesozoic sediments as well as Precambrian sediments. Some of the Paleozoic and Mesozoic sediments include important aquifers which not only produce ground water in the Western province, but also provide recharge areas for important ground water systems below the Central and Eastern provinces.

Igneous rocks (solidified from a molten magma) penetrate, cover, and are covered by sedimentary rocks, particularly in the southern part of the Western province. The hard bedrock types are increasing in importance as sources of ground water, since the ground water in the unconsolidated alluvial fill of the valleys has been appropriated. Springs are associated with the bedrock units particularly along fault zones, but may also discharge from unconsolidated sediments. Springs may also come from solution channels in carbonate rocks.

Geology of the Intermontane Valleys

Generally, the flat central portion of the valleys in western Montana consists of permeable stream-worked gravel and sand resting in stream-cut depressions in underlying semi-consolidated Tertiary (older) sediments, often exposed in terraces along the valley sides. Tributary streams flowing from mountain canyons to the main stream in the valley have cut valleys in the Tertiary sediments. These tributary stream valleys which may be floored with permeable gravel may extend back through canyons cut in solid rock as much as several miles to sources of water from mountain snow.

The thickness of the loose stream-washed gravel and sand may be as much as several hundred feet in some of the valleys, and the thickness of the underlying Tertiary sediments is much greater. The bottom of the Tertiary and Quaternary sediments in some of the valleys, such as the Bitterroot and Missoula valleys, is below the present stream outlets flowing on solid bedrock.

The older, semi-consolidated Tertiary sediments were deposited in lakes or formed the broad, flat plains bordering the major streams, which at one time meandered over the valley floors. These

sediments consist of layers of gravel and sand with predominant fine silt and many layers of bentonitic clay formed by the weathering of old volcanic ash falls. During the more recent Pleistocene time (the period characterized by glaciation), glacial till, glacial stream deposits of gravel and sand, and glacial lake silt and clay were deposited on top of the eroded Tertiary sediments and older rocks. Much of western Montana was at that time under the waters of the extensive glacial lakes Missoula and Kootenai. These lakes were formed by ice dams to the west and north. Near the end of the ice age, the ice dams were broken or over-topped by impounded water, and catastrophic flooding followed. The lakes drained and streams cut rapidly downward through the lake deposits and older Tertiary sediments to form the present drainage pattern.

Central Montana

Physiography and Climate

The Central Geographic Division of Montana (Figure 2.3) is east and north of the eastern front of the Rocky Mountains. It is part of the Great Plains which extend over all of eastern Montana. Central Montana is characterized by isolated mountain ranges rising above a broad, high plain, which has been sculptured by numerous stream and river valleys. The mountain ranges include the Sweetgrass Hills, Big Snowy, Judith, Moccasin, Little Rocky, Bearpaw, and Highwood Mountains.

The highest of these summits attain elevations of over 11,000 feet, but the area receiving the greater precipitation common to higher elevations is only a fraction of those in western Montana. The large rivers and streams in eastern Montana are supplied mainly by headwaters in western Montana.

The broad plains surrounding the island-like uplifts have a semi-arid climate. In average years, the plains are suitable only for grazing or dryland crops. Irrigated lands are present in the major tributary valleys, in the vicinity of the large highlands, and in some areas of the plains.

Bedrock Geology

The bedrock of central Montana is of great importance in any considetation of ground water occurrence. The bedrock of central Montana consists of stratified sedimentary rocks ranging in age from Precambrian to Tertiary. The dominant rock strata exposed at the surface are of Cretaceous (Mesozoic) age, although exposures of older Mesozoic and Paleozoic strata occur around and within most of the mountain uplifts.

Several aquifers of permeable sandstone or fractured and cavernous limestone are present in central Montana. One of the oldest (and potentially the most prolific) aquifers is the Madison limestone, which is exposed over large areas in the Little Belt, Big Snowy and Bighorn Mountains. Above the Madison is the Kibbey Sandstone. The Swift Formation is known to yield water in the Judith Basin area. The Second and Third Cat Creek sandstones of the Kootenai Formation are aquifers and supply many flowing wells in the Judith Basin area. The Eagle-Virgelle Sandstone, Judith River, Fox Hills, and Hell Creek formations also contain ground water. Under favorable geologic conditions, wells tapping them will flow. Sandstone layers, fractured coal beds and clinker of the Fort Union formation also yield water.

Interlayered between the aquifers are small to great thicknesses of shale. This shale is in the Montana Group (Bearpaw, Claggett) and Colorado Group (Thermopolis, Skull Creek, Mowry, Graneros, Greenhorn, Carlisle, Niobrara) which yield little if any ground water (what water they contain is often of poor quality). These materials are important because they prevent the leakage of water from one aquifer to another and prevent the loss of hydrostatic pressure. The total thickness of the material from the base of the Madison limestone to the Fort Union formation in central Montana, may be as much as 5,000 feet.

Some of the isolated mountains in the Central Province are cored by igneous rocks which have little porosity and generally low permeability.

Geology of the Unconsolidated Sediments

Most of the surface bedrock of central Montana is covered by unconsolidated rock debris consisting of glacial drift, older gravels, recent alluvium, and soil.

Glacial Deposits

Much of central Montana north of the Missouri River is covered by glacial deposits left when the Pleistocene ice melted away about 10,000 years ago (Figure 2.2). The ice-deposited till usually contains large pebbles, cobbles and boulders, but is mostly a fine-grained material derived from Mesozoic muds in the Colorado and Montana groups. The till often has low permeability and is capable of yielding insignificant to small amounts of water to wells. In some areas, sand and gravel were deposited by streams flowing from the glaciers (outwash). These outwash deposits may take the form of sheets (but also occur in shoe-string-shaped channels from ancient rivers). These outwash deposits are typically more permeable and yield larger amounts of water than the till. In some cases these glacial-stream deposits also have water of better

TABLE 2.1. Estimated withdrawals in Montana, millions gallons per day (mgd) rounded to nearest 1 mgd (figures may not add to the totals due to independent rounding), (USGS, 1993).

	Irrigation	Public Supply	Industrial Self- Supplied	Livestock	Fossil Fuel Power Use	Mining	Rural Domestic	Total (all uses)
Ground Water	90	51	30	16	0	15	15	218
Surface Water	8,910	83	27	35	33	4	1	9,100

quality than that in the till deposits. The glacial deposits may be 100 feet or more thick, though generally are present only as scattered deposits of unconsolidated clay and boulders.

Older Gravel Deposits

Deposits of high-level terrace gravel (100 feet or more in thickness) occur around the flanks of the Big Snowy and Little Belt Mountains and cover a part of Judith and Wheatland Basins.

Post-Glacial Alluvium

Portions of the Clark's Fork of the Yellowstone, the Yellowstone, Missouri, Judith, Musselshell, Sun, and other rivers occupy broad valleys filled with alluvium. The alluvium consists of gravel, sand, silt, and clay deposited by the river as it changed its channel from one portion of the valley to another. The alluvium in the river valleys may range from thin layers to deposits 40 feet (or more) thick below the river bed. The alluvium may be from a few feet to several miles in width.

Eastern Montana

Physiography and Climate

The Eastern Geographic Division (Figure 2.3) of Montana comprises all eastern Montana east of the central Montana mountain uplift area. Eastern Montana is characterized by a rolling, and sometimes irregular plain, deeply cut by the Missouri and Yellowstone Rivers and their many tributaries. There are no mountain uplifts in eastern Montana (although stream erosion has formed hills with a relief greater than 1,000 feet).

The average annual precipitation in eastern Montana is about 12 inches. There is a wide range in the amount of precipitation from year to year and from one area to another during any one year. However, the climate is semi-arid and precipitation is inadequate to support any crops other than dryland crops, or to maintain perennial stream flow. The major sources of water supply are the larger streams such as the Missouri, Milk, Yellowstone, Bighorn, and Powder Rivers.

Bedrock Geology

The bedrock is an important source of water in eastern Montana. The bedrock aquifers supply most of the stock water, as well as household and municipal needs in areas away from the larger valleys. The bedrock of eastern Montana consists of sedimentary strata of Tertiary and Cretaceous age.

The aquifers within common drilling range are permeable sandstone layers or coal beds. Deeper aquifers are usually permeable sandstone, although the Madison limestone is known to yield significant amounts of ground water in at least one area (but the water quality is poor).

In general, the same bedrock aquifers which occur in central Montana are present in eastern Montana. However, their importance in production of ground water is different. Aquifers are present in the sandstone, fractured lignite, sub-bituminous coal, and in the clinker formed during natural underground burning of coal. Principal ground water-bearing units include the Fort Union Formation, the sandstone layers of the Hell Creek Formation and the Fox Hills Sandstone which overlays the Bearpaw shale. The Judith River Formation with several water-bearing sands lies below the Bearpaw and overlays the Claggett Shale. The Eagle Sandstone, which is an important aquifer in the Central Geographic Division, contains too much silt and shale to be an aquifer. The Judith River Formation is the lower and most exposed bedrock aquifer in eastern Montana.

Aquifers below the Judith River Formation include the Fall River Sandstone, Kootenai sandstone beds (Lakota) and the Madison limestone. These aquifers generally lie between 2,000 and 7,000 feet below the surface throughout most of eastern Montana.

Geologic structures in eastern Montana are not as prominent as those in central Montana, but gentle folds do expose some of the aquifers.

Geology of the Unconsolidated Sediments

The surface bedrock of eastern Montana is generally covered by unconsolidated rock debris of types similar to that in central Montana: glacial drift, older gravels, recent alluvium, and soil.

Glacial Drift

Glacial debris similar to that described in the section on central Montana is abundant north of the Missouri River (Figure 2.2). Aquifers in glacial stream deposits north and east of Wolf Point are important sources of ground water.

Older Gravel Deposits

Deposits of older gravel occur on the plateaus north of the Milk River. High-level deposits of this gravel, known as the Flaxville gravel, underlie glacial drift in a large area in northeastern Blaine County and in several large areas in Valley, Daniels, and Roosevelt Counties. Similar gravel of possibly more recent age are present along the east and west sides of the Bighorn River (near and south of Hardin). The more northern gravel deposits are the remnant alluvial deposits of an older river system which drained northeastward into Canada.

Post-Glacial Alluvium

The alluvium of the river valleys in eastern Montana is the most important aquifer present in that region. The valleys of the major rivers may be several miles in width and may be filled with permeable sand and gravel to depths of 100 feet or more. Many of the smaller tributary valleys, which are dry during most of the season have sufficient alluvium below the stream channel to maintain subsurface flow throughout the year.

TABLE 2.2. Well use in Montana (MBMG, 1992).

Purpose	Number of Wells
Domestic	72,830
Stock Water	38,389
Irrigation	5,467
Public Water Supply	1,391
Industrial	1,066
Commercial	1,026
Monitoring	2,233
Research	858
Recreation	232
Fire Protection	187
Institutional	297
Medical	28
Water Flood	94
Injection	8
Test Wells	132
Wildlife	1
Unused / Abandoned	1,606
Other	595
Unknown	6,842
Total Number of Well Records Evaluated:	**113,857**

Note: Some wells may be used for more than one purpose.

Statewide Ground Water Use

Ground water is the source for nearly 40% of public water supply withdrawals, nearly 80% of withdrawals for mining uses, over half of industrial use (self-supplied) withdrawals, and about 30% of livestock use withdrawals. Irrigation accounts for over 40% of total ground water withdrawals in Montana. Table 2.1 and Figure 2.4 show estimated withdrawals of ground and surface water for several categories of use.

Table 2.2 compares water use for 7 major use categories derived from 113,857 well logs in the Montana Ground Water Information Center (GWIC) at the MBMG. Ground water from wells is used for more than one purpose. The largest single use of ground water in Montana is for domestic purposes (55%). Agricultural purposes, such as irrigation and stock watering account for 33% of the wells used in Montana (GWIC, June 1992) (Figure 2.5).

1. Rural domestic use

Approximately one-half of Montana's residents rely on ground water as their source of water for domestic uses, through both public and rural water supply systems (USGS, 1993). Per capita use averages about 78 gallons per day (gpd) for rural users and about 129 gpd for publicly supplied users.

Private domestic supplies use 72,830 wells, or 54.6% of the total number of wells in Montana (GWIC, June 1992). The 204,000 rural residents of Montana use approximately 16.0 mgd of water for domestic purposes, almost 95% of which is derived from ground water sources.

2. Municipal domestic use

Recent estimates indicate that 595,000 people (almost 75% of Montana's population) are served by public water supply systems. A public water supply is defined as a water system "for the provision of water for human consumption from any community

well, water hauler for cisterns, water bottling plant, water dispenser, or other water supply that serves 10 or more families, or 25 or more persons daily, or has at least 10 service connections at least 60 days out of the calendar year" (Administrative Rules of Montana (ARM) 16.20.202). The 1,391 wells provide ground water which is the source for nearly 40% of withdrawals for public water-supply systems statewide (GWIC, June 1992). Domestic use accounts for 77 mgd of a total of 134 mgd delivered by public water-supply systems. Of the remaining 57 mgd delivered, 25 mgd is supplied for commercial uses, and 32 million gallons is attributed to public use (parks, etc.) and system losses.

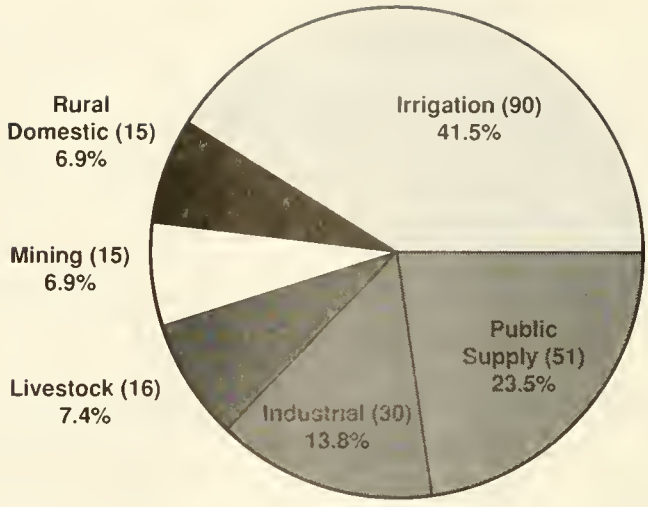


FIGURE 2.4. Estimated ground water withdrawals in Montana during 1990, rounded to nearest 1 mgd, (USGS, 1993).

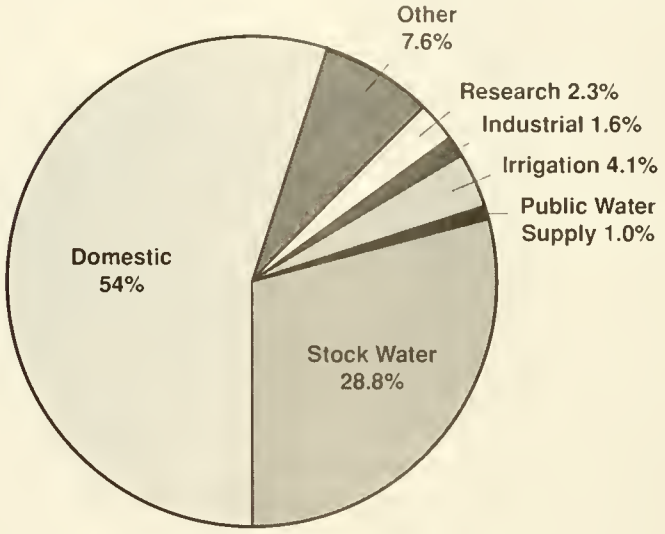


FIGURE 2.5. Montana's well use (MBMG, 1992).

3. Industrial use

Industrial and commercial facilities use 2,092 wells (GWIC, June 1992). Industrial use accounts for about 14% of the ground water withdrawn in Montana. Of a total of 58 mgd of ground water withdrawn for industrial purposes, about 21 mgd are used in Missoula County, and about 13 mgd in Lincoln County. Ground water is the source of water for over half of the industrial uses in the state.

4. Agricultural use

There are 43,856 wells used for domestic purposes: of these, 38,389 wells are used for stock watering and 5,467 wells are used for irrigation (GWIC, June 1992). Irrigation of crops accounts for 98% of ground water withdrawals in Montana (about 9,000 mgd), however, only 22% of the water withdrawn for irrigation is actually used by plants. Canal leakage and irrigation return flows account for most of the remaining 78% of water withdrawn. Ground water supplies about 1% of total irrigation withdrawals. About ten percent of ground water withdrawals for irrigation are in Flathead County.

5. Instream flow

Ground water contributes to the flow of many streams and plays an important role in maintaining stream flow during low-flow periods. Springs serve as the source of water for many Montana Department of Fish, Wildlife and Parks (MDFWP) hatcheries (Personal Communication, Rehwinkel, MDFWP).

Two state agencies have applied and have been granted to the Department of Natural Resources and Conservation (DNRC) for reserved water rights for instream flow protection in various streams throughout the state. The MDFWP has been granted reservations to: protect fish and wildlife habitat; contribute to and maintain a clean, healthful and desirable environment; and to sustain adequate levels of water quality. The MDHES has been granted reservations for the main-stem Missouri River to dilute naturally occurring arsenic, especially during low-flow periods.

6. Recreational use

Recreational uses such as golf course and city park irrigation are

classified by the DNRC as irrigation if they are self-supplied. Included in this category are cemeteries, many of which are irrigated. Public supply systems provide water for many of these facilities. About 230 wells are used for recreational purposes according to 1992 GWIC data.

7. Wildlife use

Many wildlife species, particularly aquatic birds are dependent upon wetland habitats which are influenced by ground water.

Cited References

Bergantino, Robert N. 1992. Montana Bureau of Mines and Geology Open-file Report 246 A-D. Montana Bureau of Mines and Geology, Butte, MT.

Cheng, H.H and W.C. Koskinen. 1986. Processes and factors affecting transport of pesticides to ground water. In: Evaluation of pesticides in ground water. American Chemical Society, Washington, D.C.

Driscoll, Fletcher G. 1986. Groundwater and Wells. 2nd ed. Johnson Division Publishing, St. Paul, MN.

Ferreira, Rodger F., M.R. Cannon, and Robert E. Davis. 1987. Montana ground-water quality, national water summary 1986. United States Geological Survey Water Supply Paper 2325. United States Geological Survey, Helena, MT.

Fettet, C.W. 1988. Applied Hydrogeology. 2nd ed. Macmillan Publishing Co., New York, NY.

Freeze, R. Allan and John A. Cherry. 1979. Groundwater. Prentice-Hall Inc., Englewood Cliffs, NJ.

Groff, S.L. 1958. The ground-water situation in Montana. Montana Bureau of Mines and Geology Information Circular 26. Montana Bureau of Mines and Geology, Butte, MT.

Ground Water Information Center, (GWIC). Montana College of Mineral Science and Technology, Butte, MT.

Heath, R.C.. 1983. Ground-water regions of the United States. United States Geological Survey Water Supply Paper 2242. United States Geological Survey, Helena, MT.

Levings, J.F., Robert E. Davis, and Charles Parrett. 1985. Montana ground water resources, national water summary 1984. United States Geological Survey Supply Paper 2275, pp. 285-290. United States Geological Survey, Helena, MT.

McKenna, D.P., S.C. Schock, E. Mehnert, S.C. Mravik, and D.A. Keefer. 1989. Agricultural chemicals in rural, private water wells in Illinois: recommendations for a statewide survey. Cooperative Ground Water Report 11. Illinois State Geological Survey and Illinois State Water Survey. N.p.

Miller, Kathleen. 1993. Water movement on the land surface and in the soil. Figure. Unpublished. Montana Bureau of Mines and Geology, Butte, MT.

Montana Department of Natural Resources and Conservation. 1986. Montana water use in 1980. Montana Department of Natural Resources and Conservation Report. Montana Department of Natural Resources and Conservation, Helena, MT.

National Academy of Sciences. n.d. Report from Committee on Techniques for Assessing Ground-Water Vulnerability. 2102 Constitution Avenue, N.W., Washington, D.C.

Parrett, C. 1990. Montana water supply and use, national water summary 1984. United States Geological Water Supply Paper 2350, pp. 337-344. United States Geological Survey, Helena, MT.

Rehwinkel, Bruce. 1992. Personal communication. Montana Fish, Wildlife and Parks, Helena, MT.

Solley, W.B., R.R. Pierce and H.A. Perlman. 1993. Estimated use of water in the United States in 1990. United States Geological Survey Circular 1081. United States Geological Survey.

United States Environmental Protection Agency. November 1991. Drinking water regulations and health advisories. United States Environmental Protection Agency, Washington, D.C.

United States Geological Survey. 1993. Provisional data. Unpublished, Helena, MT.

For a list of publications of geologic and hydrogeologic research conducted in Montana, see the Montana Bureau of Mines and Geology Publications Catalog, MBMG, Montana College of Mineral Science and Technology, Butte, Montana.

Chapter 3

Factors Contributing to Agricultural Chemicals in Ground Water

Pesticide Residues and Nutrients in Ground Water and Surface Water Environments

Ground water stored within the shallow alluvial aquifers of Montana river valleys may be susceptible to impairment from *nonpoint sources*. Shallow alluvial aquifers are sources of drinking water for both rural and public water supplies. Surface water in the valleys is also highly susceptible to agricultural chemical impairment from surface runoff, and by impairment through ground and surface water interaction.

Agricultural chemicals can enter ground and surface water through:

- drift from spray application,
- hydraulic connection with ground water,
- surface runoff (water and soil) from cropland,
- irrigation return flow,
- recharge of ground water,
- improper mixing/loading procedures utilized at mixing/loading facilities,
- applications to cropland,
- improper storage facilities, and
- accidental spills.

Agricultural activities, including irrigation of crops, conducted on land overlying shallow aquifers, can aid downward migration of salts, trace elements, and agricultural chemicals until they reach the ground water. The migration of an agricultural chemical into surface water is dependent on the following:

* properties of the agricultural chemical,
* rate of application,
* soil type,
* slope of field,
* type of crop,
* length of time between application and rainfall, and
* whether a buffer zone that has no agricultural chemicals applied exist between cropland where these chemicals have been applied and the surface water.

Methods that prevent pollution from agricultural chemicals should be implemented wherever these chemicals are stored, applied, and disposed. Once these chemicals enter ground water they are difficult and expensive to remove. In some cases it is impossible to completely remove the contaminant from ground water.

Sources of Impairment

Nonpoint Sources of Impairment

Nonpoint source impairment from agricultural chemicals may occur from normal application of agrichemicals to range or cropland, although it has never been documented in Montana. Normal implies that the agricultural chemical is labeled for use on the crop and pest at the application site and that all label directions and use restrictions have been followed. Nonpoint impairment is also presumed to result from small rates of agricultural chemicals applied over large areas. Impairment from normal field applications may result if conditions exist that are favorable for the material to readily move through the soil into a shallow aquifer. This type of impairment is difficult to detect without extensive sampling, and equally difficult to trace to an identifiable source. Impairment may be classified as nonpoint until a detailed site investigation indicates otherwise.

Point Sources of Impairment

Point source impairment is the release of agricultural chemicals from specific incidents or identifiable sources. Montana statute (75-5-103, MCA) defines a point source as a discernable, confined, and discrete conveyance such as a pipe, ditch, barrel, or vehicle. Examples of point source releases of agricultural chemicals include:

- leakage from faulty nozzles,
- mixing and loading sites,
- storage facilities,
- application equipment,
  - hoses,
  - tanks,
  - valves
- overflows from tanks,
- leaking containers,
- back siphoning into wells,
- improper disposal of containers or pesticides,
- accidents resulting in chemical spills, and
- improper washing of application equipment.

Aquifer Sensitivity/ Vulnerability

Aquifer sensitivity, refers to the native susceptibility of an aquifer to agricultural chemical impairment. Sensitivity is related solely to the hydrogeologic characteristics of the aquifer and the overlying geologic materials. Sensitivity is not related to land use practices and/or contaminant toxicity. Aquifer vulnerability is defined as the susceptibility of an aquifer to impairment resulting from the combined effects of native sensitivity of the aquifer and the land-use practices (EPA, 1991).

The rate of ground water movement is directly related to the hydraulic conductivity of the aquifer in which it is contained. Hydraulic conductivity is a measure of the capacity of material to transmit water. Natural earth materials have a very wide range of hydraulic conductivities. Near the earth's surface, there are very few, if any, geologic formations that are absolutely impermeable because of weathering and fracturing processes.

An aquifer which underlies a confining layer is generally less sensitive to impairment from activities taking place on the ground surface immediately above the aquifer. Ground water moves through a confining layer if that layer contains vertical cracks or fractures; nevertheless, the rate of movement is very slow. Confined aquifers may be vulnerable to surface activities (for example, pesticide application) that are taking place in the recharge area, and can be contaminated by drill holes which connect water-bearing zones of differing water quality.

An aquifer may be recharged from precipitation, surface water or other aquifers. If land-use activities contaminate any of these sources of recharge, the receiving aquifer is judged to be vulnerable and the land-use practices should be carefully scrutinized.

Many variables affect aquifer sensitivity, therefore it is unwise to give general recommendations as to which depth an aquifer may be considered "safe" or "unsafe". All hydrogeologic factors must be considered simultaneously on a case by case basis. Certain surface characteristics may be used to approximate the location and depth of ground water. The presence of wetland plant species, soil mottling and signs of seasonal flooding are parameters that may indicate a high water table.

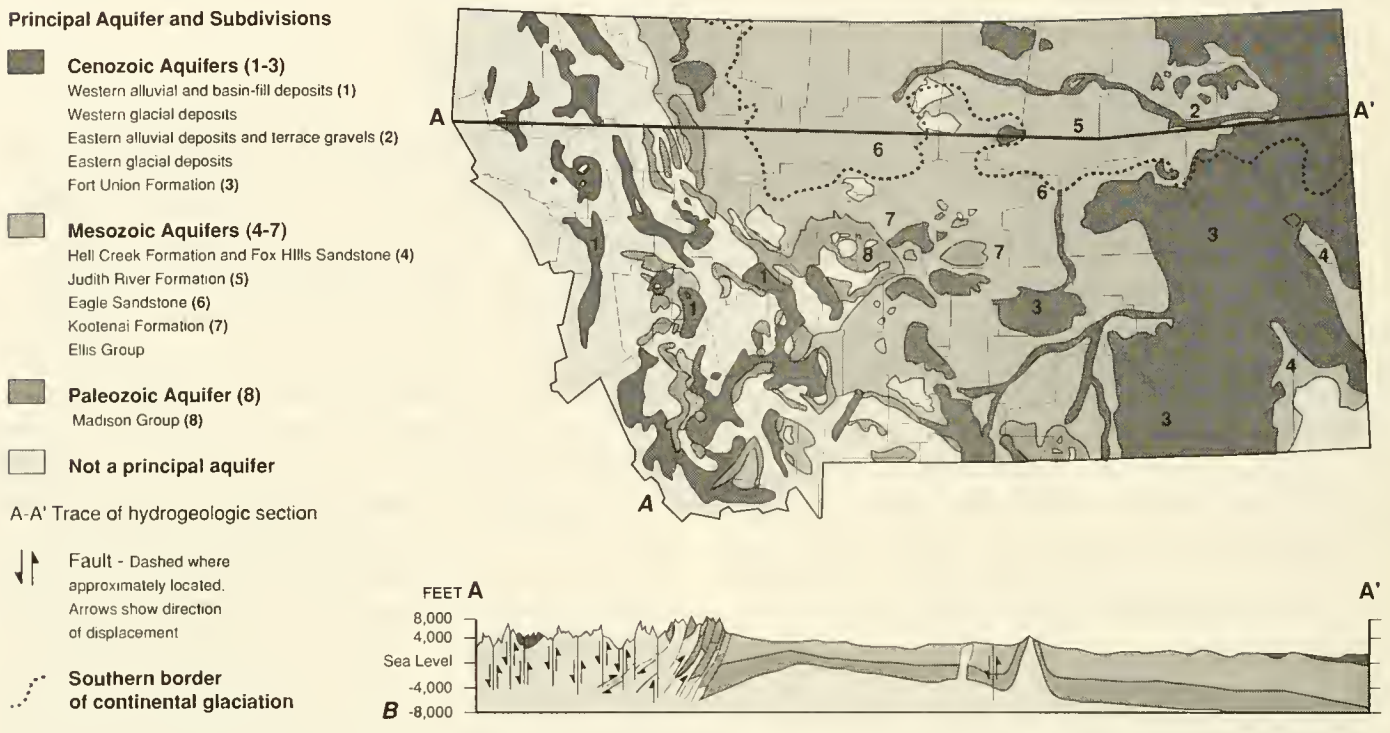
The variability of Montana geology dictates that the evaluation of aquifer sensitivity due to physical/geologic characteristics be performed on a site by site basis. Surface and subsurface characteristics determine an aquifer's sensitivity to surface impairment and the subsequent movement of contaminants through the vadose (unsaturated) zone. Relevant subsurface characteristics include hydraulic conductivity, the presence or absence of a confining layer, hydraulic gradient, transmissivity, ground water flow velocity, permeability, and the size, distribution and continuity of pores.

Detailed statewide data on regional aquifer characteristics are not available. However, the Montana Bureau of Mines and Geology (MBMG) has produced a series of general maps showing the location of major aquifers in Montana. These maps are to assist in the classification and prioritization of ground water vulnerability to non-point source pollution (Figure 3.1). The maps are at a scale of 1:1,000,000 and delineate the outcrops (recharge areas) and subcrops of the following aquifers:

- unconsolidated sand and gravel deposits (alluvium, glacial outwash, terrace deposits, and Flaxville Formation and equivalents),
- Fort Union Formation,
- Fox Hills and Hell Creek Formations,
- Judith River Formation,
- Eagle/Virgelle Sandstone, and
- Kootenai Formation.

The Montana Ground Water Assessment Act of 1991 (2-85-901 et seq. MCA) will systematically fund efforts to evaluate Montana's

FIGURE 3.1. Principal aquifers and subdivisions (Ferreira, 1987).



ground water resources. The major purposes of the Act are to:

* Coordinate Montana's ground water data collecrion and information distribution effotts.
* Develop an extensive and well planned statewide ambient water-level and water quality monitoring network.
* Create a 21 year program to systematically evaluate Montana's ground water resources.

The Assessment Act is administered by the MBMG and a statewide Steering Committee. Scientists from the MBMG in cooperation with local, state and federal agencies will characterize individual aquifers in 21 areas (which are from one to five counties in size). Each investigation will take three years to complete. Bureau scientists will compile information on the geology and ground water resources of each study area, conduct additional drilling, and testing to more accurately map the geology and determine the distribution and properties of the aquifers. They will also collect and analyze ground water samples to evaluate water quality and better understand ground water flow systems. The final product of each study will be a series of maps showing the location, depth and thickness of aquifers. Other maps will show ground water flow directions and identify the principal recharge areas for the aquifers. This information will be used to evaluate the relative vulnerability of aquifers to impairment. The report for each area will also address issues related to ground water management, protection and development.

Some Factors Which Contribute To Aquifer Vulnerability Assessment

1. Chemical Transport

The transport of pesticides through the soil and the vadose (unsaturated) zone into ground water is affected by a number of properties in the soil. The adsorption process can retain chemicals on the surface of soil particles and retard movement with percolating water. The commonly used pesticides are mostly organic

chemicals and can be degraded partially or completely to inorganic end products by chemical, photochemical or biochemical means. The by-products of pesticide degradation, however, can also present environmental problems. Pesticides can also be transported to the atmosphere by volatilization, to surface water by runoff from soil or be removed from soil by plant uptake. Whether circumstances for transport of pesticides to ground water exist will depend upon a combination of factors including the chemical nature of the pesticide, the soil properties, geologic materials, and climatic and environmental variables (Figure 3.2). Realistic assessment of the potential for transport of pesticides to ground water must include simultaneous evaluation of all the processes and factors that may affect the transport process (Cheng and Koskinen, 1986).

2. Irrigation Management

Highly mobile sodium, magnesium or calcium salts may occur in some soils. These salts are easily leached from the soils during periods of moisture surplus. Ground water may be established above impermeable zones if vegetative uptake of soil moisture is insufficient to prevent migration of water to below the root zone. Movement of this ground water is principally responsible for the occurrence of saline seeps. Agricultural chemicals applied to these lands may leach into this shallow ground water. The shallow ground water is often high in nitrate and total dissolved solids.

The application of irrigation water in excess of that needed for optimal plant growth can enhance pesticide and nutrient movement to the saturated zone. A higher ratio of irrigated to non-irrigated cropping occurs in western Montana. Cropped areas in western Montana are usually found in valleys because of the shallow soils and topographic restrictions of adjacent foothills.

3. Climate

A continental weather system, characterized by wide fluctuations in temperature and precipitation within and between years, dominates much of Montana. Moderate maritime/temperate weather systems influence weather conditions west of the divide. Drought conditions are expected every 3-5 years out of 10. Fallow cropping is typically used to compensate for irregular precipitation. Soil-water storage (approximately 30% is stored) from fallow years supplements precipitation for the next year's growing season.

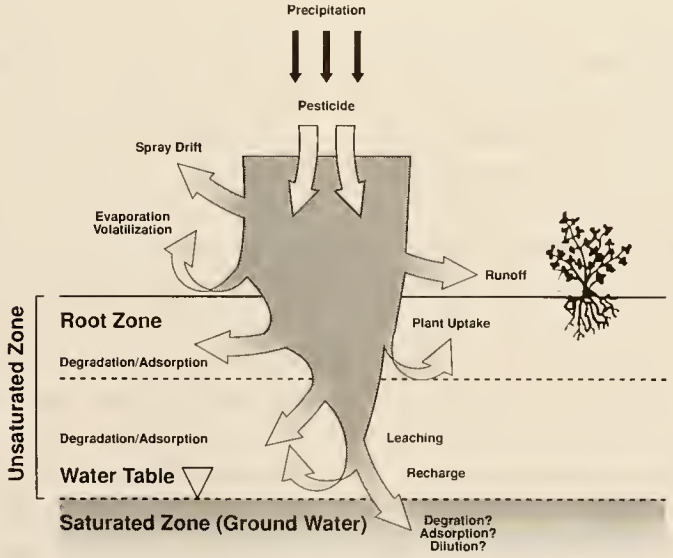
4. Soils

Soils are composed of sand, silt and clay particles in varying percentages (soil texture). The textural class provides an estimate of the size of particles. The larger and more uniform the particles, the greater the ease of water movement through the soil.

Clayey soils usually have low percolation and infiltration rates and therefore, are subject to runoff, which can collect in low-lying areas where water tables may be nearer the surface. Shallow aquifers overlain by heavy clay may be degraded by the migration of contaminants from the surface through vertical fractures in the clay. Cracks, which may be fairly wide and extend to depths of 10 feet, can develop in clayey materials as the soil dries. Surface runoff may wash soil fines and resuspended compounds deep into the soil before the surrounding soil has swelled to close the crack. Coarse textured soils have high percolation and infiltration rates which increases the likelihood of leaching. With lower water holding capacity, coarse soils are much more susceptible to contaminant movement.

"Soil properties play a major role in controlling the rate and nature of downward movement of chemicals through the soil. The primary mode of transport is mass flow in which dissolved pesticides move with percolating water. In the unsaturated zone, mass flux of a chemical is directly related to the hydraulic conductivity of the soil and indirectly related to the texture, water content, bulk density or porosity, and pore size distribution of the soil"

FIGURE 3.2. Potential pathways of pesticide loss and transport (modified from McKenna, 1989).



(McKenna, 1989).

"The soil properties that most directly affect potential leaching of reactive compounds such as pesticides are organic carbon content and hydraulic conductivity. Nitrate, a nonreactive anion, is highly water soluble and not subject to adsorption to organic matter or clays. Consequently, the rate of nitrate movement is controlled by the rate at which the soil water moves. Under certain conditions, however, nitrate may undergo denitrification and subsequent volatilization" (McKenna, 1989).

5. Cropping systems

Most field studies for the determination of pesticide registration requirements are not conducted in the Great Plains. Hence, the combination of environmental considerations unique to our region such as organic matter, soil pH, soil moisture, and soil temperature, may not be factored into assessments of pesticide leachability and persistence (Table 3.1).

Pesticide and fertilizer use varies yearly according to weather and market fluctuations. The type of crop produced determines the types and amounts of agricultural chemicals used. Moreover, the cash value of the crop will often dictate the willingness of the grower to apply agricultural chemicals as a means of crop protection (pesticides) or to incrementally boost yield (fertilizers).

In Montana, dryland small grains production accounts for the majority of farmed acreage. Herbicides are the most commonly used pesticide on these lands, for both fallow and cropland weed control. Insecticides are rarely used on dryland small grains unless locally abundant populations of insect pests reach or exceed economic thresholds. Grasshoppers, cutworms and Russian wheat aphids are the principle insect pests that may warrant action by growers. Insecticides registered for these pests are not expected to degrade ground water through leaching. *In most years, the risk of pesticides leaching into ground water from dryland production is minimal because there is no surplus soil moisture to transport agricultural chemicals below the root zone.* Pesticides leaching into ground water from dryland crop production most likely occurs from surface tunoff ponding in low-lying areas where the distance between soil surface and water table is decreased, or from pesticide migration through vertical fractures in the soil.

The greatest risk to ground water impairment may occur on irrigated ground. Crops such as malting barley, potatoes, mint, and sugar beets command higher market prices, and are more closely monitored for pest problems. These crops also require a higher degree of quality control due to their value-added properties. Pesticides are used more on these crops, as small differences in crop damage or quality may mean large differences in price received. A wider spectrum of pesticides are commonly used: including fungicides, insecticides and herbicides. Multiple applications of any of the previously mentioned pesticides may also be used to control persistent or recurring pests.

Pesticides

Factors That Influence Pesticide Leaching

The potential for pesticide introduction into ground water exists wherever pesticides are used. The potential varies with the chemical properties of the pesticide, the soil and other factors such as volatilization (loss to the atmosphere), decomposition, soil adsorption, and transport by water. Volatilization and decomposition reduce the total amounts of pesticides available for downward movement. Soil adsorption decreases the availability of the pesticide for downward movement and transport by water. In addition, small quantities of pesticides are retained and removed from the soil by agricultural products.

The amount of pesticide applied affects the potential for ground water impairment. The potential for movement to ground water of relatively mobile water-soluble pesticides is increased where large amounts have entered or built up in the soil.

Solubility. *Solubility* is the ability of a pesticide ro dissolve in water. As the solubility of a pesticide increases, there is a greater potential for transport to ground water (leachate) or surface water (runoff). Pesticides with solubilities below 30 ppm are considered to have relarively low potentials for leaching. If the solubility is 1 ppm or less, the product will tend to remain at the soil surface, but may move off-site with soil sediment. The solubility of a pesticide tends to decrease with an increase in dissolved salts and increase in the presence of dissolved organic matter.

Persistence. The *persistence* of a pesticide under a given set of conditions is expressed in terms of the length of time required for 50 percent of the pesticide to decompose to products other than the original pesticide. This is referred to as the half-life ($T_{1/2}$) of the pesticide. The persistence of a pesticide is one of the most important factors in determining its leaching potential. Pesticide persistence is categorized as non-persistent (half-life of 30 days or less), moderately persistent (half-life of 30 to 99 days), or persistent (half-life greater than 100 days).

TABLE 3.1. Selected pesticide properties which influence leaching (values are not absolute), (Chemical and Pharmaceutical Press, 1990, Meister Publishing Co., 1992, USDA-ARS, 1990, USDA-SCS, 1990, Wauchope, 1990).

Pesticide	S (ppm)*	$T_{1/2}$ (days)	K_{oc} (ml/g)	Leaching Potential
Atrazine	33.0	120	100	High
Carbaryl	120.0	10	157	Low
Clopyralid	1,000.0	30	6	High
2,4-D Acid	890.0	10	80	Medium
Diazinon	65.0	31	500	Medium
Dicamba	6,500.0	20	8	High
Dimethoate	25,000.0	7	8	Medium
EPTC	375.0	30	280	Medium
Fluazifop	2.0	15	5,700	Low
Glyphosate	90,000.0	50	24,000	Low
Malathion	145.0	1	1,800	Low
Metribuzin	1,220.0	30	41	High
Metsulfuron	6,000.0	105	40	High
Pendimethalin	.3	90	24,300	Low
Permethrin	.2	32	86,000	Low
Picloram	430.0	200	16	High
Triallate	4.0	82	2,400	Low
Trifluralin	.3	90	7,000	Low

* S = Water Solubility $T_{1/2}$ = Soil Half-life K_{oc} = Soil Adsorption Potential

Retention by soil. Retention of organic pesticides by soil particles is referred to as *adsorption*. Adsorption decreases the concentration of pesticides in solution and thus decreases the availability for downward movement in water. Also, adsorption increases the length of time pesticides are available for decomposition by microorganisms in the biologically active surface soil. Pesticides are retained by soils to different degrees, depending on the properties of the pesticide, the soil, and their interaction.

The most important soil property that affects adsorption is organic matter content. The greater the organic matter content, the greater is the adsorption. Another important soil property influencing adsorption is clay content. The higher the clay content, the higher the adsorption capacity of the soil (McBride, 1998). The calculated soil adsorption potential is referred to as the K_{oc}.

Hydrolysis. Some pesticides react with water in soil to form new compounds. This process is known as *hydrolysis*, and varies with soil pH. Pesticides can hydrolyze to form new compounds which may have pesticidal properties or be rendered inactive.

Volatilization. Pesticides that are *volatile* (high vapor pressures) and have a low water solubility tend to be readily vaporized or converted to a gas and lost from the soil to the atmosphere. They are unlikely to be transported into the soil. Pesticides that are volatile and readily vaporized are generally substances, such as fumigants, which allow for the pesticide to move readily throughout the material to be fumigated (insecticides can also be fumigants). Generally, fumigants are more volatile than insecticides and insecticides are more volatile than herbicides. Air temperatures also play a major role in controlling volatilization.

Decomposition. Sunlight breaks down organic molecules. This process is referred to as *photodecomposition*. Most herbicides, insecticides and fungicides are decomposed to some extent by sunlight. Photodecomposition rate of agricultural chemicals in surface water is dependent mainly on the intensity of the sunlight and the depth of the contaminant within the body of water.

Microorganisms. The predominant means of pesticide decomposition in soil is carried out by *microorganisms* and to a smaller extent by plants. Fertile soils contain millions of microorganisms per ounce of surface soil. Pesticides can serve as sources of nutrients and energy for microorganisms. The rate of microbiological breakdown of pesticides varies with the pesticide chemical structure, pesticide concentration, soil moisture, soil temperature, organic matter, pH, nutrients, soil fertility, availability of microbial population, and plant cover. Rapid degradation of pesticides in soils is one of the major reasons certain pesticides that exhibit mobility have not been detected in ground water.

*TABLE 3.2. A list of pesticides commonly used in Montana. (Chemicals names taken from Farm Chemicals Handbook, 1993, Meister Publishing Co., 1992).

Chemical Family	Common Name	Trade Name
Insecticides		
Carbamates	aldicarb**	Temik
	carbaryl	Sevin
	carbofuran**	Furadan
Organophosphates	acephate	Orthene
	azinphos-methyl	Guthion
	chlorpyrifos	Lorsban
	diazinon	Diazinon
	dimethoate	Cygon
	disulfoton	Disyston
	fonofos	Dyfonate
	malathion	Cythion
	methamidophos**	Monitor
	mevinphos	Phosdrin
	oxydeprofos	Metasystox
	parathion	Parathion
	phorate	Thimet
	trichlorfon**	Dylox
Pyrethroids	esfenvalerate	Asana
	permethrin	Pounce
Fungicides		
Acetanilide	metalaxyl**	Ridomil
Benzimidazoles	benomyl**	Benlate
Chlorinated Benzontile	chlorothalonil	Bravo
Dicarboximides	dichloran	Captan
Dithiocarbamates	maneb	Maneb
	mancozeb	Dithane
	thiram	Thiram
Imidazole	imazalil	Flo-Pro
Inorganic Compounds	copper hydroxide	Coppercide
	copper sulphate	Kocide
	sulfur	Polyram
Triazoles	propiconazole	Tilt
	triadimefon	Bayleton
Oxathlin	carboxin	Vitavax

Chemical Family	Common Name	Trade Name
Herbicides		
Acetanilides	alachlor	Lasso
	propachlor	Ramrod
	propanil	Stampede
Aryloxy Phenoxy-Carboxylic Acid	diclofop-methyl	Hoelon
	quizalofop-ethyl	Assure
	fenoxyaprop-methyl	Tiller
	fluazifop-butyl	Fusilade
Benzoic Acids	dicamba**	Banvel
	chloramben**	Amiben
Benzonitriles	bromoxynil	Buctril
Bipyridiliums	paraquat	Gramoxone
	difenzoquat	Avenge
Carbamates	desmedipham	Betanex
Cyclohexanone	sethoxydim	Poast
Dinitroanalines	ethalfluralin	Sonalan
	pendimethalin	Prowl
	trifluralin	Treflan
Diphenyl Ethers	acifluorfen	Blazer
Phenoxy-Carboxylic Acids	2,4-D**	Weedone, many more
	2,4-DB**	Butoxone
	MCPA	Weed-Rhap, many more
Pyridines	picloram**	Tordon
	clopyralid**	Stinger
Substituted Amino Acids	glyphosate	Roundup
Sulfonyl Ureas	metsulfuron**	Ally
	thifensulfuron-methyl**	Harmony
Bentazon	basagran**	Dalapron
Thiocarbamates	triallate	Fargo
	EPTC	Eptam
	cycloate	Ro-Neet
Triazines	atrazine**	Aatrex
	cyanazine	Bladex
	metribuzin**	Sencor
	simazine**	Princep

* Table lists commonly used pesticides and does not include all pesticides used or registered in Montana.
** Indicates that the chemical has a high leaching potential.

Calculating Leaching Potentials

Methods of predicting aquifer vulnerability have focused primarily on the development of models to assist in the complex analysis of all factors which affect the transport of contaminants to ground water.

Physical and mathematical models have been developed to improve the understanding of these complex processes. Some of the mathematical models that have been developed to evaluate specific soil/pesticide/management/climate combinations are CMIS (Chemical Migration in Soils), GLEAMS (Ground Water Loading Effects of Agricultural Management Systems), LEACHMP (Leaching Model for Pesticides), and PRZM (Pesticide Root Zone Model) developed by the Environmental Protection Agency (USEPA) for pesticide registration decisions.

In realistic terms, it is beyond the scope of models to accomplish vulnerability assessments in a state as environmentally complex as Montana.

Some of the problems encountered with modeling approaches are:

1. The use of chemical properties of active ingredients in pesticides, constant mobility is assumed, vapor diffusion is neglected and actual applied pesticide formulation is poorly understood (active ingredient, inert ingredient, surfactants, etc.).

2. Hydrologic budget is simplified and actual water flow is poorly understood and too complex for model use (variable direction, infiltration, evaporation, transpiration, etc.).

3. Delay of chemical transformations can not easily be modeled and transformation of chemical may yield breakdown of products with different mobility, persistence and toxicity.

4. Tabulated soil adsorption potential (K_{oc}), soil half-life ($T_{1/2}$), and water solubility (S) values vary widely under actual conditions (Mackay, 1992).

Of all the properties which influence the potential for a pesticide leaching into ground water, soil adsorption potential (K_{oc}), soil half-life ($T_{1/2}$), water solubility (S), and hydraulic conductivity are the most important (Table 3.1).

Of all the values listed above, the K_{oc} plays the most significant role. A pesticide which has a low K_{oc} value is susceptible to movement in solution through the soil profile and into ground water. However, if the $T_{1/2}$ is also low, the potential for movement is lessened due to rapid degradation of the pesticide.

It should be clear that field conditions must be integrated with pesticide chemistry factors before determining that a pesticide is susceptible to leaching. The only reliable method for determining the loss pathways of a pesticide is from experiments under actual field conditions. However the time, expense, large number of chemicals, and the wide variety of field conditions, make it likely that models will play a significant role in these assessments. Prior to acceptance and use of model predictions, models should be evaluated for accuracy by extensive in-the-field testing (Cheng, 1990 and Water Science and Technology Board, 1990).

TABLE 3.3. The content of plant essential elements in the earth and in the soil (Lindsay, 1979).

Element	Content in the Earth Average	Common Range for Soils	Selected Average for Soils
	%		
B	.0001	.00002 - .0010	.0001
C	.0095	—	.2000
Ca	.3600	.07000 - 5.000	.1370
Cl	.0050	.00020 - .0090	.0010
Cu	.0070	.00002 - .00100	.0003
Fe	.5100	.07000 - 5.5000	.3800
K	.2600	.00400 - 3.0000	.0830
Mg	.2100	.00600 - .06000	.0500
Mn	.0090	.00020 - .03000	.0060
Mo	.00023	.000002 - .00005	.00002
N	—	.00200 - .04000	.0140
O	4.6500	—	4.900
P	.0120	.00200 - .05000	.0060
S	.0060	.00030 - .10000	.0070
Zn	.0008	.00010 - .00300	.0050

Some of the herbicides that are used in the production of small grains have high leaching potentials and belong to the chemical families of benzoic acids, phenoxy-carboxyl acids, sulfonylureas and pyridines (Table 3.2). Even though these herbicides have high leaching potentials, a large portion are used in dryland production areas (6.2 million acres) which are not susceptible to leaching due to low precipitation and ground water aquifers contained in low yield bedrock or covered with 50 feet or more of materials exhibiting low permeability. However, there are approximately 470,000 acres of irrigated small grains in the state where the irrigation water combined

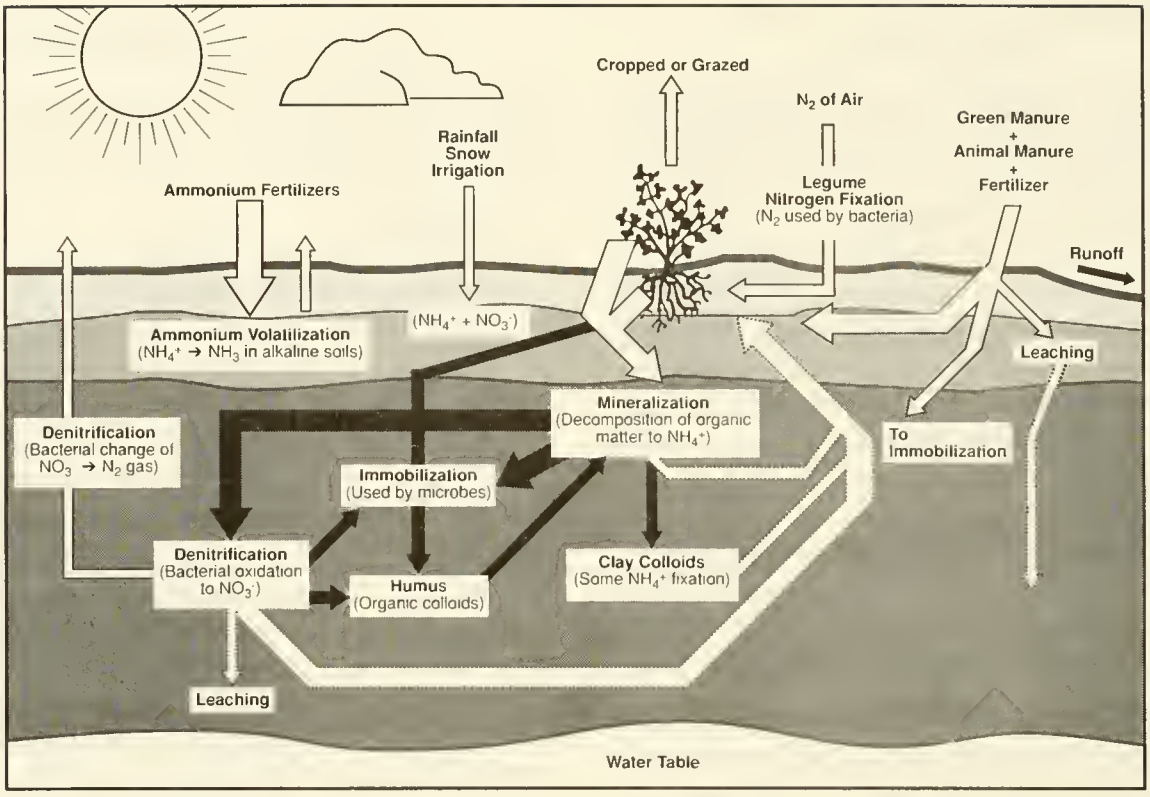


FIGURE 3.3. Nitrogen cycle—many transformations determine the fate of soil N (Jacobsen, 1991).

with aquifers located in alluvium, glacial-outwash or fractured bedrock makes these acreages susceptible to contamination. Additionally, there are approximately 175,000 acres of irrigated specialty crops that are susceptible to contamination problems. The types of crops found in these areas include: corn, sugar beets, canola, dry beans, seed potatoes, mint, lentils, squash, and peas. These irrigated specialty crops may use one or more pesticides which have a high leaching potential during a production season.

Plant Nutrients

Plants require proper amounts of nutrients to grow (Table 3.3). Three nutrients, carbon (C), hydrogen (H), and oxygen (O), make up about 95% of plant dry matter and are supplied in large amounts from atmospheric gases and water. Nitrogen (N), phosphorus (P) and potassium (K) come from the soil and are the nutrients most likely to be deficient. The secondary nutrients, calcium (Ca), magnesium (Mg), and sulfur (S) are also needed by plants in relatively large amounts, but are less often deficient.

Through the decomposition of plant residue, nutrients contained in plant tissue are recycled back to the soil. Each nutrient element is involved in some type of continuous cycle in which it is taken up by plants and microorganisms, incorporated into plant and animal tissue, released, changed, and involved in a variety of soil transformations. The reactions and pathways making up the cycle are different for each nutrient. For example, both N, C, O, and S are contained in air and alternate between solid and gaseous forms. The processes involved in nutrient cycling determine the rate of nutrient release in the soil, and the fate of applied nutrients.

Nutrients are added to the crop/soil system through the addition of fertilizers, manure, sludge, crops, precipitation, and irrigation water. Nutrients can be lost from the cycle through leaching, erosion, chemical transformation, and crop harvest. Nitrogen, P and K, in particular, are removed in large quantities by crop harvest, and must be replaced through use of fertilizers or other sources of readily available nutrients. An understanding of nutrient cycling pathways, rates of change, inputs, and losses-

provide management opportunities to benefit crop production. This section discusses the cycling of major plant nutrients and relationships to crop nutrient supply.

Nitrogen Cycle

Nitrogen exists in many forms, which change continuously through various processes in the N cycle (Figure 3.3). Because N is so widely limiting in crop growth, the N cycle is one of the most important processes in nature. Most soil N is contained in organic marter and released at a rate of only 2-3% per year. Dead plant tissue decays releasing ammonium (NH_4^+)—a process called mineralization. Ammonium is then rapidly converted to nitrate (NO_3^-) by nitrification. Both ammonium and nitrate are easily taken up by plants and microbes. The tie-up of N by soil microbes is referred to as *immobilization* because the N is temporarily unavailable to plants. The amount of N in soil water as ammonium and nitrate is usually less than 2% of the total soil N, except following recent applications of N fertilizer or manure.

Ammonium and nitrate are both highly soluble. Because nitrate is not adsorbed to soil colloids, it is subject to loss by leaching. Nitrate can also be converted to N gases by soil microbes and lost to the air (denitrification). Denitrification is encouraged by poor soil aeration, where oxygen is limiting (saturated soils), bacteria obtain oxygen from NO_3 and release N gas. Nitrogen is also lost through runoff, erosion and crop harvest. Fertilizer N is subject to these same losses.

Seventy-eight percent of the atmosphere is N_2 gas that cannot be used directly by plants. This represents a virtually unlimited supply of N when converted to a usable form. Atmospheric N is used in the manufacture of N fertilizers. It is also made available to plants through the process of N fixation, carried out by certain kinds of soil bacteria. Biological N fixation is the principal means by which atmospheric N enters the soil-plant system. Legumes, such as peas, beans, clovers, and alfalfa have a unique association with N-fixing bacteria that colonize their roots and supply plant-available N. The relationship between legumes and nodule bacteria is an example of a symbiotic association. Some free-living bacteria also fix N. Nitrogen fixation represents a significant N input that can reduce the need for N fertilizers.

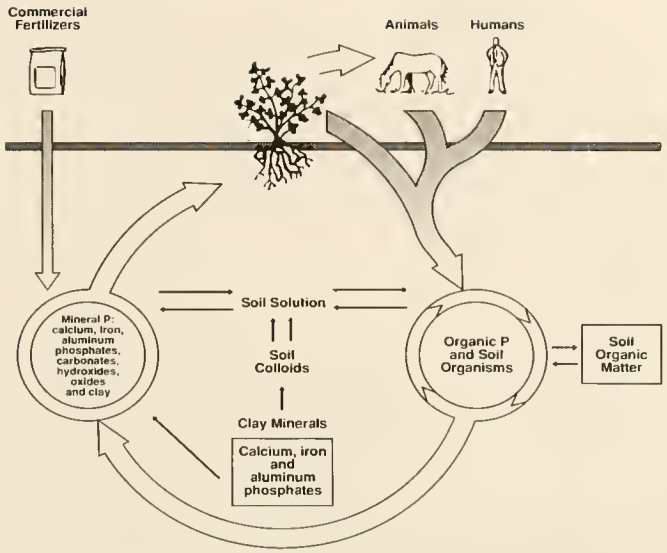


FIGURE 3.4. Phosphorus cycle—most P must be liberated from mineral and organic compounds in order to be used by plants (Tisdale, 1985).

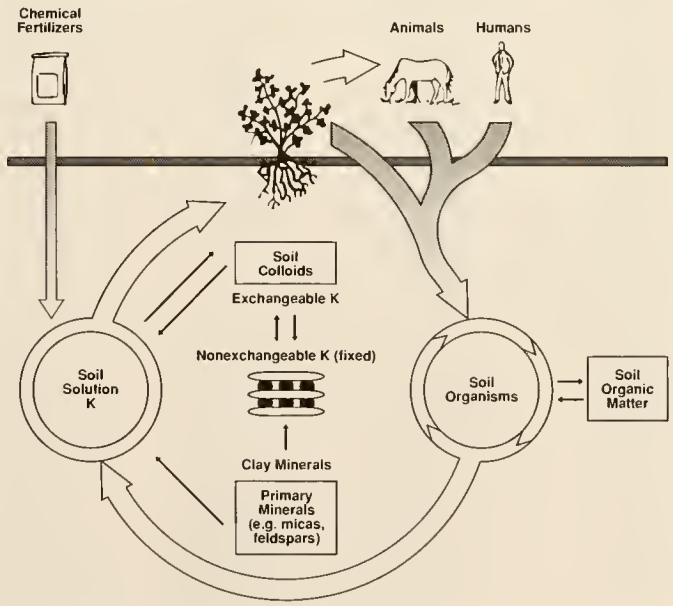


FIGURE 3.5. Potassium cycle—K released from plant residue and animal waste is readily available to plants (Tisdale, 1985).

Phosphorus Cycle

Phosphorus (P) is contained in rock minerals, plant and animal tissue, water, and soil (Table 3.2). Plants take up P only in the form of the

phosphate ion, $HPO_4^{=}$ or $H_2PO_4^{-}$, which at any given time represents a small proportion of total soil P. Aside from that applied as fertilizer, much plant available P is from organic matter decomposition. In this way, P is cycled between plants, animals, and soil (Figure 3.4).

In the soil, P exists in many forms, most of which are unavailable to plants. Unavailable P is tied up in insoluble, organic and inorganic compounds, or tightly bound to clay surfaces. The P reserve most readily available to replace P removed by plants is referred to as "labile" P. This portion of the soil P is very important to soil fertility and is the quantity normally measured in a soil test. The rate at which P is released depends on the forms present, soil chemistry, temperature, and the soil pH, among other variables.

Only 20-30% of the P added as fertilizer is used by a crop in a given year. A large proportion of added P is "fixed" (made less available) in the soil. In high-calcium soils, P is fixed primarily by combining with calcium carbonate (lime). Over the long-term, most of the fixed P is available. While not considered "fixed", some added P is also tied up by microorganisms (immobilization).

Most soil P is complexed with and bound to soil particles, organic compounds, and

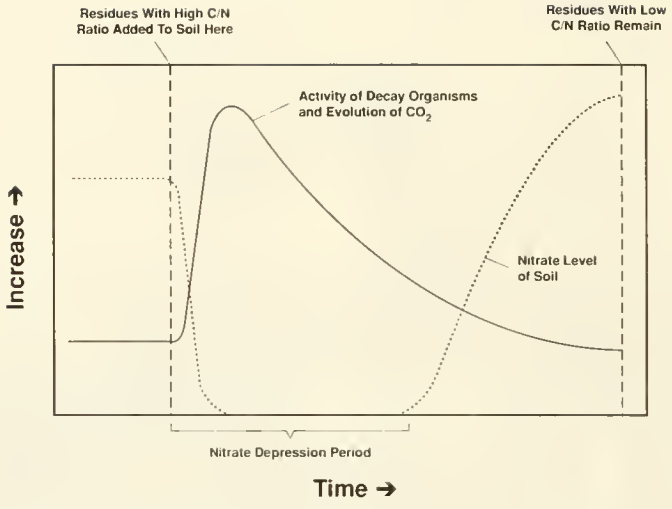

Residues With High C/N Ratio Added To Soil Here
Residues With Low C/N Ratio Remain
Activity of Decay Organisms and Evolution of CO_2
Nitrate Level of Soil
Increase →
Nitrate Depression Period
Time →

FIGURE 3.6. Changes in plant-available N due to the addition of organic material with high C:N ratio. After organic material is broken down, final soil nitrate level is higher than original (Tisdale, 1985).

TABLE 3.4. Total N, P and K fertilizers sold in Montana from 1971-1992 (MDA, 1971-1992).

Year	Nitrogen	P_2O_5	K_2O
	----------	Tons	----------
1971	41,207	56,834	1,262
1972	43,913	50,154	2,504
1973	52,840	62,346	2,983
1974	45,961	60,786	4,225
1975	39,029	43,973	3,155
1976	53,982	62,989	5,725
1977	64,024	74,294	8,609
1978	53,982	59,816	5,298
1979	76,382	78,997	10,292
1980	64,889	57,450	8,759
1981	86,440	70,069	10,836
1982	115,046	77,620	12,367
1983	118,811	75,163	11,147
1984	115,449	72,347	11,967
1985	91,414	63,891	10,426
1986	96,082	64,049	10,453
1987	120,496	74,166	11,815
1988	117,088	71,858	12,275
1989	117,854	73,254	12,825
1990	115,766	69,962	13,059
1991	111,257	68,258	15,332
1992	130,158	74,111	15,739

cations. Little P exists in solution at any given time, frequently less than 1 ppm, so that there is virtually no possibility of leaching. The major avenue of P loss from the system is through soil erosion and, because P tends to be concentrated in the surface soil, erosion losses can be large.

Potassium Cycle

Potassium (K) is generally very abundant in the soil (Table 3.3). It is not uncommon to find soils with 40-60 thousand pounds of K in the top 6 inches of the soil. However, most of this is contained in clay minerals and not readily available to plants. In the K cycle, the bulk of K is contained in living plant tissue and unweathered (primary) rock minerals (Figure 3.5). Within the plant, K exists in simple forms, and rapidly leaches out of dead plant tissue and into the soil.

Only 1-2% of the total soil K exists in soil water at any given time and leaching losses are generally low due to retention on exchange sites. However, leaching can still be a problem on sandy soils or where large amounts of K fertilizer are applied. In the soil, potassium occurs in relatively unavailable forms in unweathered rock minerals (amounts released in one growing season are negligible), slowly available forms in clay particles, and exchange-

able (readily available) K. The greatest potential for loss of exchangeable K is through soil erosion.

Soil Microorganisms

Through microbial decomposition, organic matter is converted to humus and then gradually broken down to simpler organic forms. In the process, plant nutrients are released. Many diverse groups of organisms, both plant and animal, are found in the soil, but not all are involved in organic matter decomposition. The release of nutrients from organic matter is carried out by organisms that use organic or inorganic compounds in the soil as an energy source. Bacteria and fungi are the most widespread, abundant, and active soil organisms. They are present in very large numbers on the surface of soil particles and are primarily distributed in the surface horizons.

Although soil microbes as a group, especially bacteria, are adapted to a wide range of living conditions, some generalizations can be made about the conditions they require, particularly with "typical" agricultural soils. In general, microorganisms involved in organic matter decomposition:

- exist mostly in surface soil layers, to depths determined by aeration and the presence of organic matter,
- are stimulated by moist, warm conditions and an organic food supply,
- multiply very rapidly when conditions are suitable,
- have the capacity to tolerate unsuitable conditions by becoming dormant, and
- release nutrients tied up in organic matter.

TABLE 3.5. Average amount of NO_3-N remaining in soil (0-24") by cropping system (Jacobsen, 1991).

Average Residual Soil NO_3- N Level	
Cropping System	**Pounds Per Acre**
Alfalfa	40-80
Fallow	55
Double fallow	85
Cereal grain-dryland	25
Cereal grain-irrigated	20
Legume green manure	80-90
Annual legume	40
Other cultivated crops	25-30

Carbon: Nitrogen Ratio

The ratio of C to N in soil or organic materials measures the rate at which organic material will decay. The C:N ratio of a soil is fairly stable in the absence of major organic inputs—usually between 10:1 and 12:1 for most agricultural soils.

Organic materials containing low N have high C:N ratios (for example, 90:1 for sawdust or tree bark). Conservation tillage systems may also influence N requirements. Soil organisms require N to decompose organic matter, and the more organic matter present, the more N required. In the presence of low-N materials, microorganisms compete with plants for available N, and soil N may be depleted for a time (Figure 3.6). As the organic material is converted to humus, C is released as carbon dioxide (CO_2), and the C:N ratio of the soil decreases. Ammonium which is not immobilized by microorganisms is available for nitrification, which results in the production of nitrate.

TABLE 3.6. Average nutrient composition of common animal manures (Jacobsen, 1991).

Source	Total Solids	N	P_2O_5	K_2O	lbs/animal per day	N	P_2O_5	K_2O
	-----------%-----------					----- Pounds Per Ton ------		
Beef feedlot	32	0.71	0.64	0.89	60.0	14	13	18
Dairy	21	0.56	0.23	0.60	70.0	11	5	12
Swine	25	0.50	0.32	0.46	9.0	10	6	9
Horse	30	0.69	0.23	0.72	51.0	14	5	14
Poultry (no litter)	46	1.56	0.92	0.42	0.2	31	18	8
Sheep	35	1.40	0.48	1.20	4.0	28	10	24

Commonly Used Nutrient Sources

Nitrogen, P and K are the three commonly used fertilizers in Montana. Nitrogen is used in greater amounts throughout the State compared to other fertilizers (Table 3.4). Nitrogen can also be added to the soil from precipitation, manure, N fixation, crops, and cropping systems. Long-term soil test records suggest that the amount of NO_3-N in the soil following various crops can be predicted reasonably well in Montana (Table 3.5). Nitrogen, as NO_3-N, is highly soluble and moves through the profile under high precipitation or irrigation. The crop's N requirement depends upon the estimated yield potential, management ability, crop quality, residual NO_3 levels, local environment, soil, variety, historic yields, economics, and related production factors.

Phosphorus is relatively immobile in the soil. Although considered immobile in the soil, K is somewhat more mobile than P. Phosphorus and K nutrient additions are based on preplant soil tests, crop to be grown, placement methods, and economics. It is also important to recognize that animal manures provide additional sources of N, P, and K (Table 3.6). The nutrient quality of the manure will be dependent upon the source of manure, age, and storage and handling practices. Manure application rates should be based on a manure analysis integrated with the factors enumerated under N, P, and K fertilizer use practices.

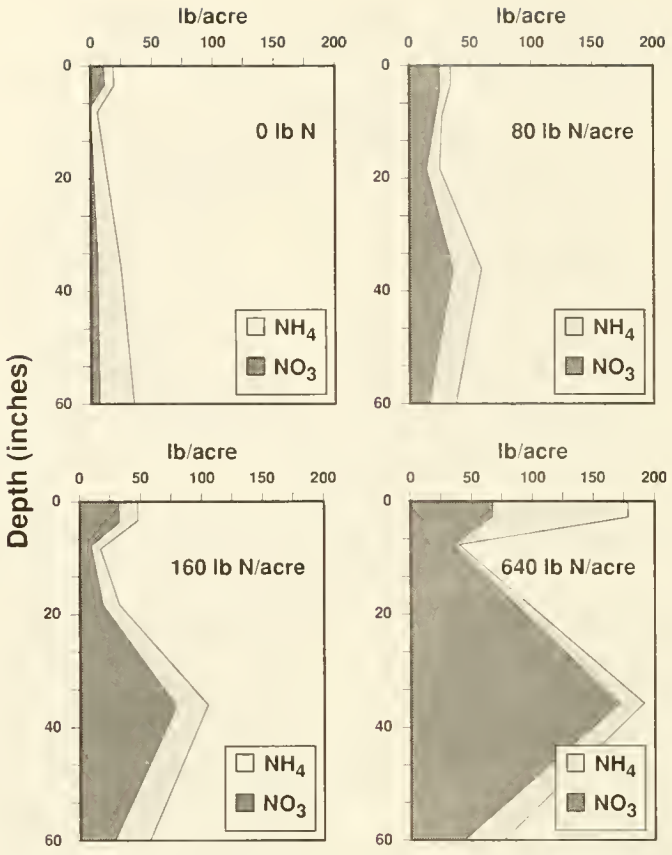


FIGURE 3.7. Distribution of nitrate- and ammonium- N as influenced by rate of applied N, after one growing season (127 days) under fallow. Total precipitation was 9 inches (University of Nebraska Extension Service, QRS- 1972)

Factors That Make A Plant Nutrient Leachable

Movement of Nutrients in Soil

The mobility of a nutrient determines both how easily it can be utilized by plants, and its potential for loss through leaching. The loss of nutrients via leaching is not only uneconomical and may reduce crop yields, but may be a source of ground water impairment.

Nitrogen Movement

Most plant-available N is in the form of nitrate (NO_3^-), which exists primarily in the soil water and is therefore, extremely mobile in soil. Ammonium (NH_4^+) is also highly soluble, but because of its positive charge, tends to be adsorbed on clay and organic marter particles and is held in the root zone. The depth to which nitrate moves depends on amounts of precipitation, irrigation and the water-holding capacity of the soil.

Nitrate loss through leaching occurs when combined amounts of rainfall and irrigation exceed the water holding capacity of the soil. Once leached out of the crop root zone, nitrate can enter ground water. Factors that determine the leaching potential of a given soil are: the initial water content, soil texture and coarse fragment content, presence of an impermeable layer, crop selection, and crop rooting depth.

Figure 3.7 illustrates, for one growing season, 1) changes in the proportions of ammonium and nitrate after addition of ammonium nitrate fertilizer (34-0-0) at various rates, and 2) movement

of nitrate downward through a soil profile under fallow. Only natural precipitation was received, amounting to less than 9 inches over the 127-day growing season. A crop growing on this soil would have used much of the added N (approximately 125 lb N for a 60 bushel/acre wheat crop) and prevented downward movement. However, this example illustrates the fate of N applied in excess of crop needs or at a time when plant utilization is minimal.

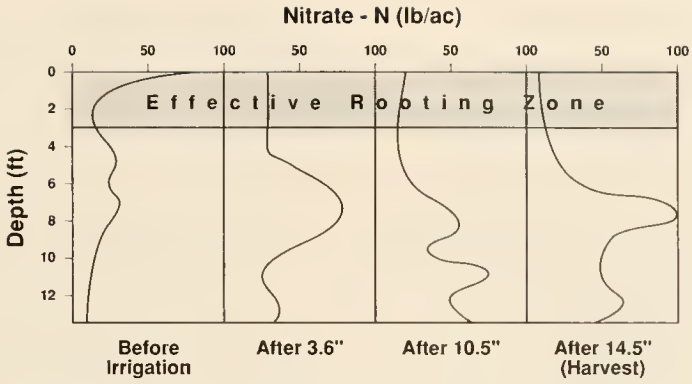


FIGURE 3.8. Nitrate movement in a Blanchard loamy sand under potatoes (MAES, unpublished).

In dryland soils, the highest nitrate concentrations often occur in fall, in fallow soils, due to the cumulative mineralization of organic matter over summer. Fall rains then provide an opportunity for nitrate leaching. Under most circumstances, accumulated fall precipitation alone is not sufficient to move nitrates out of the rooting zone.

Sandy soils offer the greatest potential for nitrate leaching because of their low water holding capacity. Sandy soils are mostly found in Lake County north of Ronan, and in Flathead County north of Kalispell. Four out of 13 shallow domestic wells spot checked in this area were found to contain nitrates in excess of the recommended limit of 10 ppm NO_3-N.

Sandy soils in this area are often used for growing irrigated potatoes and mint which increases the potential for leaching. The effective rooting depth of potatoes is only about 3 ft and they are usually fertilized with high rates of N. Figure 3.8 shows nitrate movement through a Blanchard loamy sand during one growing season under potatoes. Combined precipitation and irrigation of 14.5 inches was enough to leach all of the applied N out of the root zone. In another study, potato growers were careful not to apply more water than required to fill the rooting zone deficit, and no downward nitrate movement was observed. The amount of water applied during each irrigation event is as important as the total amount applied during the year.

On a statewide scale, nitrate losses through leaching from cropland are estimated to be generally less than 25 lb per acre. Losses of this magnitude are not thought to pose a threat to ground water quality. However, in localized areas losses may be much higher, especially where intensive, irrigated farming is practiced. Improper handling and storage of nutrient sources also represents a potentially detrimental, concentrated nitrate source.

Unfortunately, fertilizers represent only one of many possible sources of nitrate in ground water (Follett and Walker, 1989). Excess ground water nitrate is often caused by high-density animal operations or septic systems. Certain areas are underlain with geologic deposits high in nitrate that can leach if irrigated or summer fallowed. Organic wastes, such as farm manure, sewage sludge, food processing wastes and crop residues, which are normally good sources of plant nutrients can become pollution sources, if handled improperly or placed near a well. One or more nitrate sources may be responsible for localized instances of ground water pollution.

Phosphorus Movement

Phosphorus ions are negatively charged like nitrate, but behave differently by reacting with clays, organic matter, cations, and inorganic compounds, most notably calcium carbonate, to form insoluble compounds. For this reason, very little of the total soil P exists in solution at any given time, making it a very immobile nutrient. As a result, little if any P is transferred from the surface to the subsoil or ground water by leaching.

Because P is bound to soil particles and concentrated in the surface soil where organic matter and fertilizers are concentrated, it can easily be lost through runoff and soil erosion. Phosphorus lost in runoff represents a loss of productivity, waste of fertilizer dollars, and a threat to surface water quality. On sloping fields or coarse-textured soils, management practices must be implemented to keep runoff and sediment from entering streams and lakes.

Phosphorus may move downward more freely in soils that are waterlogged or saturated for extended periods, because in these soils, more P exists in dissolved, organic forms. Likewise, regular additions of organic matter (residue or manure) increase the amount of mobile phosphate in the soil system.

Potassium Movement

As a cation, K^+ is strongly adsorbed on soil colloids and little exists in solution at any given time, consequently the potential for movement or leaching is small. While there is little downward movement of K in most agricultural soils, leaching can occur in sandy soils, and other soils with very low cation exchange capacity (CEC). Over time, K has been observed to move several feet in sandy soils. Excess added K may not be adsorbed and may be subject to leaching or fixation in unavailable forms. Under appropriate fertilizer rates, K leaching should be minimal. Potassium impairment of ground water is not a health threat.

Cited References

Chemical and Pharmaceutical Press. 1990. MSDS reference for crop protection chemicals 1989/90, cornbelt ed. Chemical and Pharmaceutical Press, New York, NY.

Cheng, H.H. and W.C. Koskinen. 1986. Processes and factors affecting transport of pesticides to ground water. *In*: Evaluation of pesticides in ground water. American Chemical Society, Washington, D.C.

Follett, R.F. and D.J. Walker. 1989. Groundwater quality concerns about nitrogen: nitrogen management and ground water protection. Elsevier Science Publishing Co., Amsterdam, Netherlands.

Jacobsen, Jeffrey S. and Gregory D. Johnson. 1991. Water quality and agrichemicals in Montana. Montana State University Extension Bulletin 51. Reprint. Montana State University Extension Service, Montana State University, Bozeman, MT.

Lindsay, Willard L. 1979. Chemical equilibria in soils. John Wiley & Sons, New York, NY.

Mackay, Douglas M. 1992. "Role of modeling in evaluating groundwater contamination." University of California Davis Groundwater Protection Course. University of California Davis, Davis, CA.

McBride, Dean, Dallas E. Peterson, and Arthur H. Lamey. 1988. Persistence and mobility of pesticides in soil and water. North Dakota State University Cooperative Extension Bulletin 49. North Dakota State University Cooperative Extension Service, North Dakota State University, Fargo, ND.

Meister Publishing Company. 1992. Farm chemicals handbook '92. Meister Publishing Co., Willoughby, OH.

Montana Agricultural Experiment Station. 1989. Nitrate movement. Montana State University Extension Bulletin 8904. Montana Agricultural Experiment Station, Montana State University, Bozeman, MT.

Montana Agricultural Statistics Service. 1991. Montana agricultural statistics 1991 vol. XXVIII. State of Montana, Helena, MT.

Montana Department of Agriculture. 1971-1992. Montana commercial fertilizer report, Montana Department of Agriculture, Plant Industries Division, Helena, MT.

Montana, State of. 1991. Montana codes annotated. Title 80-15-202. State of Montana, Helena, MT.

Tisdale, Samuel, Werner Nelson, and James Beaton. 1985. Soil fertility and fertilizers. Macmillan Publishing Co., New York, NY.

University of Nebraska. 1972. Distribution of nitrate. University of Nebraska Cooperative Extension Bulletin QRS-72. University of Nebraska Cooperative Extension Service, University of Nebraska, Lincoln, NE.

United States Department of Agriculture, Agricultural Research Service. 1990. Pesticide property database. United States Department of Agriculture, Agricultural Sciences Division, Beltsville, MD.

United States Department of Agriculture, Soil Conservation Service. 1990. Pesticide property database. United States Department of Agriculture, Agricultural Sciences Division, Beltsville, MD.

Wauchope, R. Don, Arthur G. Hornby, Don W. Goss, and John Bert. 1990. The SCS/ARS/CES pesticide properties data base: II using it with soils data in a screening procedure. *In*: Proceedings of the third national research conference on pesticides, November 8-9, 1990.

Chapter 4
Human Health, the Environment and Agriculture

Classification of Ground Water and Surface Water in Montana

Ground water in Montana is divided into four classes, Class I through Class IV, as specified in the Montana Ground Water Pollution Control System regulations ARM 16.20.1002. The classes are based on the beneficial uses and the specific conductance of the ground water (Table 4.1). Class I ground water rating is of the highest quality and Class IV ground water rating is of the lowest water quality.

Montana surface waters are also divided into different classifications in ARM 16.20.60.643. The surface water classifications are based on the beneficial uses of each class of water (Table 4.2).

Pesticide Residues and Nutrients

Potential Contaminants (drinking water)

Maximum Contaminant Levels (MCL)

A maximum contaminant level or MCL is the highest concentration of a contaminant allowable in a public water supply. These MCL's are specified in the National Primary Drinking Water Standards for the United States (Table 4.3). No adverse health effects are known to exist at the recommended MCL's. MCL's are based on a lifetime exposure with a consumption of .52 gallons/day of water. This provides good protection to all persons using a public water supply.

Secondary Maximum Contaminant Levels

Secondary maximum contaminant levels have been established for those contaminants that may affect taste, odor, color and appearance of drinking water. These mcl's have also been established to prevent adverse health affects. Although secondary MCL'S represent reasonable goals for drinking water, they are not federally enforceable. Yet, each state is encouraged to implement the secondary MCL's.

Health Advisories

Health advisories are guidance documents issued by the Environmental Protection Agency (EPA) that contain information on health risks, water treatment technologies, and specify levels of chemical concentrations in water that are acceptable for drinking. The EPA reviews available human data and experimental animal studies in evaluating potential human health effects. The health advisories are updated as new information becomes available.

Health Effects

Pesticide residues and nutrients in drinking water may cause health problems. Pesticides, if ingested in large quantities over a relatively short period of time may cause damage to the nervous system and internal organs of both animals and humans. Long term effects on humans are unclear and studies are ongoing. Nutrient impairment of ground water by nitrates (MCL in Table 4.3) can endanger the lives of children under the age of 1 year. Infants can develop a potentially fatal condition known as methemoglobinemia, or "blue baby syndrome". Within the infant's digestive tract, nitrate is readily converted to toxic nitrite in the oral cavity and the stomach. The nitrite is then absorbed through the infant's gastro-intestinal tract into the blood and there it bonds to ferric (Fe^{+3}) iron found in blood methemoglobin. The nitrite, thus, prevents the reduction of ferric iron back to the ferrous (Fe^{+2}) form required in hemoglobin for the transport of oxygen by blood (Follett and Walker, 1989). With greatly decreased blood-oxygen carrying capacity, the infant's tissues become oxygen-starved, the blood turns dark-brown and the skin exhibits a bluish tint. Nitrates in ground water can also be toxic to adults (Follett and Walker, 1989).

Livestock Water

Livestock require a good water supply, both in quality and quantity. Generally speaking, the maximum level of contaminants allowable in livestock water are higher than those levels acceptable for human consumption. Safe levels of agricultural chemicals in livestock

TABLE 4.1. Classification of ground water (Montana Water Quality Act, 1991).

Class	Beneficial Uses	Specific Conductance
I	Public and private water supplies; culinary and food processing; irrigation, livestock, and wildlife watering; commercial and industrial purposes.	Less than 1000 μmhos/cm at 77° F
II	Marginal for public and private water supplies, culinary and food processing; irrigation of some crops; drinking water for most wildlife and livestock; most commercial and industrial purposes.	1000 - 2500 μmhos/cm at 77° F
III	Some industrial and commercial uses; drinking water for some wildlife and livestock; irrigation of some salt tolerant crops using special water management practices.	2500-15,000 μmhos/cm at 77° F
IV	Some commercial and industrial uses only.	Greater than 15,000 μmhos/cm at 77° F

TABLE 4.2. Classification of surface water (ARM, 1988).

Class	Rule	Beneficial Uses
A-Closed	16.20.616	Drinking water, culinary and food processing after simple disinfection; swimming and recreation, growth and propagation of fishes and associated aquatic life.
A-1	16.20.617	Drinking water, culinary food processing after conventional treatment to remove natural impurities; bathing, swimming, and recreation; growth and propagation of salmonoid fishes and associated aquatic life, waterfowl and furbearers; agricultural and industrial water supply.
B-1	16.20.618	Drinking, culinary and food processing after conventional treatment, bathing, swimming, and recreation; growth and propagation of salmonoid fishes and associated aquatic life, waterfowl and furbearers; agricultural and industrial water supply.
B-2	16.20.619	Drinking, culinary and food processing after conventional treatment; bathing, swimming, and recreation; growth and marginal propagation of salmonoid fishes and associated aquatic life, waterfowl and furbearers; agricultural and industrial water supply.
B-3	16.20.620	Drinking, culinary and food processing after conventional treatment; bathing, swimming, and recreation; growth and propagation of non-salmonoid fishes and associated aquatic life, waterfowl and furbearers; agricultural and industrial water supply.
C-1	16.20.621	Bathing, swimming, and recreation; growth and propagation of salmonoid fishes and associated aquatic life, waterfowl and furbearers; agricultural and industrial water supply.
C-2	16.20.622	Bathing, swimming, and recreation; growth and marginal propagation of salmonoid fishes and associated aquatic life, waterfowl and furbearers; agricultural and industrial water supply.
I	16.20.623	Drinking, culinary and food processing after conventional treatment; bathing, swimming, and recreation; growth and propagation of fishes and associated aquatic life, waterfowl and furbearers; agricultural and industrial water supply.
C-3	16.20.624	Bathing, swimming, and recreation; growth and propagation of non-salmonoid fishes and associated aquatic life, waterfowl and furbearers. Marginal for drinking, culinary and food processing; agricultural and industrial water supply.

TABLE 4.3. Maximum Contaminant Levels (MCL) for some commonly used agricultural chemicals in Montana. If a MCL has not been assigned to a particular chemical, the health advisory number has been used (USEPA, 1992).

Agricultural Chemical	MCL	Lifetime Health Advisory
Pesticide	**- - - - mg/l or ppm - - - -**	
Alachlor	0.002	
Atrazine	0.003	
Carbaryl		0.7
Carbofuran	0.04	
Chlordane	0.002	
Dalapon	0.20	
Diazinon		0.0006
Dibromochloro-propane (DBCP)	0.0002	
Dicamba		0.2
Dinoseb	0.007	
Diquat	0.02	
Endothall	0.10	
Endrin	0.002	
Ethylene dibromide (EDB)	0.00005	
Glyphosate	0.7	
Heptachlor	0.0004	
Heptachlor epoxide	0.0002	
Lindane	0.0002	
Malathion		0.2
Methoxychlor	0.04	
Metribuzin		0.2
Oxamyl (Vydate)	0.20	
PCB's	0.0005	
Pentachlorophenol	0.001	
Picloram	0.5	
Simazine	0.004	
Terbacil		0.09
Terbofos		0.0009
Toxaphene	0.003	
2,4-D	0.07	
2,4,5-TP (Silvex)	0.05	
Nutrient		
Nitrate (as N)	10.0	
Nitrite (as N)	1.0	

TABLE 4.4. Effects of nitrate in water used by livestock (Jackson, 1983, Olson, n.d., USDA, SCS, 1982).

Reported As NO_3- N (nitrate-nitrogen)	Reported As NO_3 (nitrate)	Interpretation
0-10 ppm	0-44 ppm	Safe for all animals
10-20 ppm	44-88 ppm	Safe for all livestock unless feed is also high in nitrates
20-40 ppm	88-176 ppm	Risky, especially over long periods of time
40-100 ppm	176-440 ppm	Interference syndrome likely (trembling, weakness)
100-200 ppm	440-880 ppm	Should not be used (acute losses possible)

water, especially pesticides, have not been thoroughly examined. The agricultural water quality parameter which can pose the greatest health hazard to livestock is nitrate (especially young animals). Nitrate itself is not very poisonous, but will become poisonous when it changes to nitrite in an animal's digestive system.

Once converted, it enters the bloodstream and reacts with hemoglobin to render it incapable of carrying oxygen in much the same manner as was previously described for infants. The animal will begin to show signs of a lack of oxygen such as labored breathing and a lack of coordination. Nitrate poisoning is more likely to occur in ruminant animals such as cattle and sheep. Research also shows horses are more susceptible than swine and poultry. When livestock consume both well water and feed which is high in nitrates, the health hazard becomes even higher (Table 4.4).

Potential Contaminants

Active ingredients in a pesticide or pesticide residue are not the only potential contaminants. Carrying agents or inert ingredients may also be potential ground water contaminants. The three types

of pesticide carrying agents are: solvents, water and dry agents. A solvent-water emulsion is used as a carrying agent for a pesticide. Typical solvents include light aromatics such as xylene, chlorinated organics such as 1,1,1-trichloroethane, and mineral spirits. Water can serve as the carrying agent for a pesticide. Water-based formulations may be in the form of suspensions or emulsions. Solvent or water-based formulations can be applied directly in liquid form or as an aerosol. Dry-based pesticide formulations can be prepared by blending solid active ingredients with clay and sand as the inert ingredients. Other dry formulations are prepared by absorbing the liquid active ingredient with solid carrier agents.

Cited References

Follett, R.F. and D.J. Walker. 1989. Ground water quality concerns about nitrogen: nitrogen management and ground water protection. Elsevier Science Publishing Co., Amsterdam, Netherlands.

Jackson, G., B. Webendorfer, R. Hall, J. Crowley and D. Keeney. 1983. Nitrate, groundwater and livestock health. University of Wisconsin Extension Publication G3217. University of Wisconsin Cooperative Extension Service, University of Wisconsin, Madison, WI.

Montana State Legislarure. 1991. Montana water quality act: administrative rules. Title 16.20.10.1002. Enacted 1967, amended 1991. State of Montana, Helena, MT.

Montana, State of. 1988. Administrative rules of Montana. Title 16.20.60.604. State of Montana, Helena, MT.

Olson, O.E. and D.G. Fox. n.d. Great Plains beef cow-calf handbook, livestock water quality. Cooperative Extension Service-Great Plains States GPE 1401. North Dakota State University Cooperative Extension Service, North Dakota State University, Fargo, N.D.

United States Department of Agriculture, Soil Conservation Service. 1982. Assessing water quality for agriculture and domestic uses. Montana Technical Environmental Note No. 13. United States Department of Agriculture, Soil Conservation Service, Bozeman, MT.

United States Environmental Protection Agency, Office of Water. 1992. Drinking water regulations and health advisories. United States Environmental Protection Agency, Washington, D.C.

Chapter 5
Monitoring

The MDA and the MDHES are required by MCA, 80-15-202 to conduct ground water monitoring to detect the presence of agricultural chemical residues. *Monitoring* is the collection and analysis of water and other samples for agricultural chemical residues. Monitoring may be conducted if either department determines that sufficient scientific data is available to reasonably suspect the presence of an agricultural chemical in ground water. Monitoring is conducted on a statewide and site-specific basis.

The MDA conducts *three types* of monitoring programs:

Ambient (Background) Monitoring

Ambient (or background) monitoring is conducted by the MDA and other federal, state, and local agencies to assess the occurrence of agricultural chemical residues in ground water. Ambient monitoring is often a cooperative effort among the various technical and regulatory agencies involved in ground water. The results obtained from ambient monitoring also provides statewide baseline water quality data which can be used to evaluate or observe any changes or trends in the state's ground water quality. There are three types of ambient monitoring:

1. General Statewide

General statewide ambient monitoring is conducted on a routine basis. When the MDA started this monitoring in 1984, the selection of monitoring sites was primarily based on locating shallow wells (<50 feet deep) within a coarse or sandy soil complex. The MDA then analyzed water samples for pesticides known to have been used on crops grown in that area. While this allowed the MDA to concentrate its limited resources in what it considered to be vulnerable areas, the narrow focus resulted in defining a worst-case situation, rather than painting a picture of what was occurring statewide. In 1989, the data were summarized and revealed that of the 105 wells tested, 23 contained residues of seven different pesticides. Carbon, Jefferson, Richland, Sheridan, Teton, and Yellowstone counties had positive detections. The pesticides detected in the wells included the herbicides atrazine, 2,4-D, dicamba, MCPA, picloram and the insecticide Aldicarb. All but one of the detects were well below the mcl's or health advisory levels and presented no immediate drinking water health risk. The one detect above the health advisory was MCPA which was found at 5.5 ppb (health advisory= 4.0 ppb). Follow-up sampling of this well revealed no residues one year after the initial positive detect (1986). Follow-up sampling of the other wells with positive detects has shown that pesticide residues have disappeared. Several wells continue to show minute amounts of several herbicides (i.e., 2,4-D, picloram), but the residue levels continue to decline and none of the wells are used as a drinking water source. (DeLuca, et al., 1989).

Since 1989, the MDA has been less selective in terms of choosing to sample only wells <50 feet deep and constructed in coarse soils. Rather, the MDA has concentrated more on crop types using pesticides that the EPA has identified as having leachable characteristics. At the present time, the MDA has sampled rural domestic wells in 39 of Montana's 56 counties. Since 1989, low level detects of 2,4-D, aldicarb, picloram, and atrazine have been found. The positive detections of these compounds occurred in: Blaine, Lake, Lewis and Clark, McCone, and Missoula counties. All but one of the pesticides detected were well below the mcl or health advisory levels. The pentachlorophenol detect that exceeded the mcl of 1 ppb came from an ungrouted, hand-dug 20 foot well. Fortunately, the individual residing there was not using the well for drinking water, but it was recommended that he not use it for showering or cooking as he had done in the past.

From this discussion it should be obvious that the number and level of pesticide detections in Montana's ground water has not been great. However, the diversity of hydrogeological conditions in which pesticides have been found indicates the need to continue an active statewide ground water monitoring program (Miller, 1992).

2. Permanent Monitoring Sites

Permanent monitoring sites are long-term monitoring wells located in major crop production areas used to determine the presence of ground water impairment by specific agricultural

chemicals associated with irrigated small grain, dryland small grain, irrigated sugar beets, and irrigated seed potatoes (Figure 5.1).

Six of the monitoring well sites were developed during 1989-1990, with Toston and Mocassin being developed in 1992 and 1993, respectively. The original six wells were monitored on a quarterly basis for the first 2 years and at least twice a year since then. The two newer wells were integrated into the existing sampling schedule. Since 1993 was such a high moisture year, it is likely the wells will be sampled quarterly for at least the next year to see what impact (if any) the additional moisture has on water table levels.

Fairfield site - The infiltration of irrigation water and leakage from irrigation canals strongly influences ground water levels at the Fairfield site. The several 2,4-D detects at the Fairfield site are probably due to pesticides application up-gradient of the site and the subsequent ground water transport of the contaminant in the down-gradient direction.

Bullhead site - The Bullhead well is placed in a confined aquifer, so water quality analyses from it are indicative of practices occurring in a recharge area not immediately above or surrounding it. No pesticides have been detected at the Bullhead site.

Ronan site - Ground water levels at Ronan fluctuate in direct responses to recharge from precipitation, on-farm irrigation and leakage from irrigation canals. Nitrate concentrations are low and while no pesticides have been detected since 1990, a previous investigator found aldicarb sulfoxide at the site in 1988.

Vida site - Lithology at the Vida site, consisting of silty clayey glacial till, interbedded with gravel and thin coal beds, suggests very low susceptibility to pesticide contamination and movement. Yet a low level of 2,4-D was detected once and picloram was detected on two occasions. After recharge in 1991, no pesticides were detected. The pesticides probably gained entrance to the system through vertical cracks in the clayey glacial tills. Results from the experience challenge traditional ideas that clay lithology constitutes a "safe" environment for pesticide application.

Edgar site - This site is in an area of historical detection of carbamate pesticides. Aldicarb sulfone, a metabolite of aldicarb, was found below the detection limit in 1991. The site is lithologically sensitive to ground water contamination, and ground water levels are strongly influenced by infiltrations of irrigation water and leakage from irrigation canals.

Turner site - This site is geologically sensitive to aquifer contamination, but since much of the surrounding area is in the Conservation Reserve Program, little or no pesticides are being applied at this time. No pesticides have been detected at the site, but the nitrate concentrations are elevated.

Toston and Moccasin site - These sites are in areas of potato/small grain/hay crop rotations and small grain crops, respectively. No pesticides have been detected at either site to date. (Miller, 1992).

3. Special Projects/Basins/ Watersheds

Special Projects/Basin/Watersheds is monitoring conducted for special projects (public water supply), and/or specific basins or watersheds (Helena Valley Aquifer). Special project type monitoring is often conducted on a cooperative basis with other water resource/public health agencies.

The MDA, in cooperation with MDHES, sampled 28 rural community water supplies during 1991 and 1992. The criteria used in selecting those sampled were:

1. the system had to serve 25 people or more.
2. the drinking water came from a ground water source, and
3. the site had to be located in a rural environment.

The sites selected turned out to be several small communities using ground water as a public water supply and a number of rural schools or schools located in a rural community. Several pesticides were detected at low levels at several of the sites. The information was turned over to the Drinking Water Section in the Water Quality Bureau of the MDHES for further action.

Follow-up Monitoring

Follow-up monitoring is either in response to a complaint or a prior detection in order to *confirm* the presence of an agricultural chemical. Monitoring of additional surrounding wells is usually done to help confirm the presence and indicate any migration of the agricultural chemical residue.

Compliance Monitoring

Compliance monitoring is to determine compliance with an order, agreement or specific management plan (SMP). It is usually

FIGURE 5.1. Locations of existing permanent monitoring sites (MDA, 1993).

performed in response to a spill or misuse, or if there is a significant *probability* of an agricultural chemical entering ground water.

Quality Assurance/ Quality Control

The MDA follows an EPA approved quality assurance (QA) and quality control (QC) program. Quality assurance is a management function (policy) that assures that the quality of the monitoring program meets the required standards within a stated confidence. Quality control establishes detailed standards such as precision, accuracy, representativeness, completeness, and comparability. Quality assurance ensures that the QC function is being performed as specified. In order to establish a QA/QC program, MDA has developed the *Montana Laboratory Pesticide Quality Assurance Project Plan 1991* (MDA, 1991). The Plan meets the requirements of the EPA's "Pesticide State Management Plan Guidance for Ground Water Protection" (Review Draft, Appendix B, 1992).

Monitoring Results

The results of ground water monitoring conducted by the MDA are maintained in a ground water data base in the Helena office. In addition to the data base in Helena, the monitoring program results are incorporated into the Ground Water Information Center (GWIC) located at the MBMG. The GWIC manages a statewide ground water data base that contains well logs, lithology, water quality parameters (organic and inorganic), and site information on all recorded wells in the State. The GWIC data base contains the Minimum Set of Data Elements for Ground Water Quality established by EPA (USEPA, Appendix B, 1992) to improve the collection, accessibility, and use of ground water information by standardizing the data base elements.

The monitoring results of other agencies involved in ground water are stored in other data bases. The United States Geological Survey (USGS) uses several data bases to store ground water and monitoring data such as the State Water Use Data System (SWUDS) and the Water Quality Data Processing System

(QWDATA). Eventually, all data is transferred to the WATSTORE system and then to EPA's STORET database. The public has access to all monitoring data once they are entered into STORET/GWIC. Under provisions of a Memorandum of Understanding, the MDA and MDHES exchange all ground water monitoring results.

All positive detections of pesticide residues in ground water must be reported to the MDHES. The MDA is required to report all *positive* drinking water detections to MDHES within 48 hours of receipt of analytical results, except for detections from public water supplies or results that meet or exceed primary drinking water standards, which must be reported immediately upon receipt of positive analytical results.

Another consideration when monitoring ground water for specific pesticides is the possible presence of degradates of the compounds of interest. Pesticides can degrade to compounds that may be as toxic or more toxic than the parent compounds. Detection of these metabolites or degradation products in ground water is evidence that the parent compounds are leaching. If possible, analytical methods are selected to detect degradates as well as the parent compounds. Examples of pesticide degradates include aldicarb sulfone, aldicarb sulfoxide (from aldicarb), disulfoton sulfone, disulfoton sulfoxide (from disulfoton), and ethylene thiourea (ETU) (USEPA, Appendix B, 1992).

Cited References

DeLuca, T., et al. 1989. A survey of pesticide residues in ground water in Montana. Technical Report 89-1. Montana Department of Agriculture, Agricultural and Biological Sciences Division, Helena, MT.

Miller, Kathleen. 1992. Ground-water monitoring network to assess the occurrence of agricultural chemical residues in shallow ground water in Montana. Final Report. Montana Bureau of Mines and Geology, Montana College of Mineral Science and Technology, Butte, MT.

Montana Department of Agriculture. 1993. Permanent monitoring well locations map. Unpublished. Montana Department of Agriculture, Agricultural Sciences Division, Helena, MT.

Montana Department of Agriculture, Laboratory Bureau. 1991. Montana laboratory pesticide quality assurance project plan. Montana Department of Agriculture, Laboratory Bureau, Bozeman, MT.

United States Environmental Protection Agency. July 1992. Pesticides state management plan guidance for ground water protection: implementation document for the pesticides and ground water strategy. Draft. United States Environmental Protection Agency, Offices of Pesticides Programs, United States Government Printing Office, Washington, D.C.

—. July 1992. Appendix B: Assessment, prevention, monitoring, and response components of pesticides state management plans. *In:* Pesticides state management plan guidance for ground water protection: implementation document for the pesticides and ground water strategy. Draft. United States Environmental Protection Agency, Offices of Pesticides Programs, United States Government Printing Office, Washington, D.C.

Chapter 6
Sampling and Analysis

Impairment Sampling

Point Source Sampling

Sites used for storage, mixing and loading of chemicals have a high potential for spills which could result in point source contamination. This is due to the amount of chemicals being handled, the transfer of chemicals between containers and equipment, accidents in storage areas, leaking from application equipment, and residues from equipment washing and maintenance operation.

Sampling at point source sites can meet a number of goals, some of which include:

* identification of chemicals involved in releases,
* location of sources of point source impairment,
* definition of the horizontal and vertical extent of impairment in soil, ground water, surface water, and structures, and
* determination of the magnitude of residues in soil, water, and other media at a point source release.

An investigation at a point source site may require a two—phased approach consisting of an initial evaluation followed by more detailed sampling. Limited background information about sites, such as abandoned sites, may require that an initial evaluation be conducted to identify chemicals, to pinpoint areas of impairment, and to distinguish areas needing further sampling. Information from an initial evaluation will allow the investigator to plan more detailed sampling, to concentrate on heavily contaminated areas, and provide the laboratory with information on the ranges of residue levels.

An initial evaluation may not be required in certain situations such as confined, well documented spills. The sampler may proceed with detailed sampling or combine an evaluation with the detailed sampling plan.

Information gathered during an initial evaluation provides the basis on which a *sampling scheme* (or plan) can be developed. A sampling scheme is the logical organization of the known site characteristics, background information, and available data from which further activities (sampling strategies) can be planned. The sampler should identify the goals of sampling, the methods that will be used, and the equipment that will be needed. It should consider resources and identify the numbers and types of samples that will be collected as well as the locations and depths to be sampled. The plan should identify the analytical laboratory and the analysis that will be required. All plans should consider employee safety and describe safety procedures and protective clothing that may be necessary. Sampling schemes may take the form of a mental formulation (such as in a scheme), narrative description, or written format.

The collection and analysis of background information about a point source site is essential for development of a sampling plan.

Examples of background information include:

* the history of chemicals handled,
* the types of operations performed,
* the locations where chemicals were handled or operations performed,
* a description of soil types,
* ground water information including depth to ground water, regional flow direction, hydrogeology, and existing wells,
* topography and surface runoff features,
* a description of any spills, their locarions, amounts, and the chemicals involved,
* sensitive or critical areas where impairment could significantly affect human health or the environment, and
* a map of the site.

The background information should also include the names and addresses of persons responsible for the site and their positions of authority.

The types of media sampled at point source sites are generally limited to soil, ground and surface water, and occasionally wipe samples of hard surfaces. Residues in soil are important because they represent the cumulative impact of long-term use on a particular site with potential for leaching into underlying ground water. Residues in soils may also be an indicator of past point

source problems at a site. Soil samples can be collected from:

- spill areas,
- areas of visible impairment,
- areas of dead vegetation,
- high risk areas such as mixing and loading sites,
- equipment parking areas,
- surface runoff routes,
- areas of surface water ponding, and
- storage areas.

Soil should be collected from the surface and subsurface soil profile. Surface soil is usually sampled by taking composite samples. Composite samples are made of several subsamples from a defined area, usually within a uniform depth. Results show if the area is contaminated, which chemicals are present, and whether further sampling should be conducted. Approximately 3 to 6 subsamples can be taken in an evenly spaced grid pattern from an area about 15 feet in diameter. Surface samples should be collected from the top 0 to 6 inches of soil, or in gravelly substrates, from the 1 to 1.5 foot layer.

Subsurface soil samples will provide information about chemical leaching. Subsurface samples should be collected in high risk areas in the same locations where surface samples were collected. The depth at which samples are collected will depend upon the goals of the investigation, soil conditions, the chemical(s) present, and other site conditions. Generally, for initial investigations, samples can be collected from 2-3 feet and 5-6 feet below the soil surface. Samples are collected by trenching or using hollow stem augers designed to remove a core of soil from a desired depth. Soil borings should not penetrate into aquifers. After sampling, the bore holes should be sealed. Depending upon results, it may be necessary to sample deeper or at closer intervals.

Large rocks and debris should be removed from surface and subsurface soil samples and the samples should be screened with a 1/4 inch mesh screen. Samples can be collected in a previously unused quart canning jar with an aluminum foil seal placed between the jar and the cap. Jars should be filled approximately 3/4 full to allow for sampling mixing by the analytical laboratory. All sampling equipment and containers should be washed with soap and water and then rinsed first with distilled water, then with acetone.

Ground water samples are usually collected down gradient from point source sites where there is a potential for ground water impairment. Some of the factors entering into the decision to sample ground water include the type of chemical(s) involved, soil types, depth to ground water, and existing uses of ground water. Samples should be collected up gradient and down gradient of the point source. Existing domestic and livestock wells may be suitable for collection of samples, but it may be necessary to install monitoring wells for collection of additional samples. Each pesticide analytical method specifies sampling and preservation procedures. Therefore, the laboratory is consulted for assistance on sampling, preservation, shipping, and documentation of samples. Analytical results will determine whether residues exist that present any hazards related to drinking water consumption, irrigation, livestock watering or other uses. If residues are present, further investigation may be needed to determine the extent of contaminant migration within the aquifer and to monitor residues levels.

Nonpoint Source Sampling

The Montana Water Quality Act gives the MDHES-Water Quality Bureau broad authority for control of nonpoint source pollution through application of "all reasonable land, soil, and water conservation practices" (ARM 16.20.1011). These practices are meant to protect both present and reasonably anticipated beneficial uses (ARM 16.20.603).

The MDA and the MDHES-Water Quality Bureau have been given authority by the MACGWPA to determine if agricultural chemicals are present in ground water (80-15-202 MCA). Both Departments may respond to agricultural complaints regarding agricultural chemicals and well sample requests from citizens who suspect their wells have agricultural chemical impairment. First, an investigator collects a water sample from the well in compliance with established QA/QC. The water sample is then sent to a laboratory to determine the presence of any agricultural chemical. If the analysis reveals the presence of contaminants, follow-up samples are taken to verify the initial findings. Corroborating results will trigger further sampling in the vicinity of the original sample site to identify the source and extent of impairment. Monitoring is usually continued until residue levels fall below detection limits.

Before sampling for nonpoint pollution from agricultural chemicals, a sampling scheme or plan should (as described under point source pollution) be developed. The predominant cropping practices and agricultural chemical usage will dictate the type and quantity of samples that will be collected. Nonpoint implies the contaminant is suspected to have come from a large area and not from a localized source such as a spill. Once an area has been

selected for further investigation, agencies often review existing databases for such information as previous sampling results, well-log data and kinds/amounts of ground water usage.

Agencies involved with nonpoint sampling/monitoring employ a variety of procedures to target areas from which to collect samples. Most often, a hierarchial approach is used as a means to identify vulnerable regions or sites. This consists of developing specific site descriptions which encompass such factors as soil type, depth to aquifer, ground water flow direction, cropping practices, pesticide use patterns, or responding to public requests.

Once this information is obtained, a sampling plan can be developed. If the background investigation indicates that the agricultural chemical in question has been used in the area of concern, a radius of upgradient and downgradient wells from the contaminated well can then be sampled to determine the extent of the impairment and/or if migration of the impairment is occurring. If sampling indicates widespread impairment, the sampling radius can be increased until the extent of the impairment becomes known. If there are no wells available in the area which meet the sampling plan criteria (i.e., depth), monitoring wells may need to be installed to determine the extent and source of impairment (see water sampling suggestions in point source section). Soil samples from the area's surrounding fields where the agricultural contaminant was applied should be taken to determine levels of chemical residue present in the soil (see soil sampling procedure in point source section). In recent years, statewide, county and regional aquifer vulnerability maps have been produced by various agencies to target areas which are known or suspected to be vulnerable to nonpoint source impairment. Ground water stored within shallow alluvial aquifers of Montana is susceptible to impairment from nonpoint sources. The shallow aquifers in these areas can be the source of drinking water for both rural and public water supplies. In many instances, intensified agricultural activities such as irrigation are being conducted over these shallow aquifers, which can assist in the downward migration of agricultural chemicals. Surface water along the valleys are also susceptible to impairment from agricultural chemicals from ground and surface water interaction, direct runoff, and irrigation return flows and drains.

The MDA has developed and implemented several types of nonpoint sampling activities of ground water for agricultural chemicals. Several permanent monitoring sites are located throughout the state in major crop production areas and sampled at least twice annually (spring and fall) (Figure 5.1, Chapter 5). Ongoing "general statewide" nonpoint sampling, initiated by the MDA in 1984, has identified several areas in the state where agricultural chemicals have leached into ground water. This sampling includes domestic, irrigation, livestock, public water supply, and other individual(s) or agency(s) monitoring, or research wells. The MDA also develops and implements sampling plans for special projects where specific basins or watersheds are sampled.

Sample Analysis

Persons submitting samples for analyses must be *specific* about their analytical requests and identify specific chemicals. Selection of appropriate analyses will depend upon the quality of background information. When sampling ground water for nonpoint source impairment in a given area, a background investigation must be completed prior to sampling. This includes, but is not limited to: depth to aquifer (indexing area wells), ground water flow, seasonal water table fluctuations, agronomic practices (cropping system and others), soils, and agricultural chemical use. Samples may then be obtained using proper QA/QC procedures for sampling ground water (Montana Laboratory Pesticide Quality Assurance Project Plan, 1991).

Where little history is known about a site, multi-residue methods (MRM) for classes of chemicals will be useful. Multi-residue methods are available for phenoxy and triazine herbicides and for organophosphate, carbamate, and organochlorine insecticides. For soil samples, a phenoxy screen can provide information about recent point source impairment because this class of chemicals is widely used in Montana on small grain, pastures and roadsides. For old sites, an organochlorine screen of soil will provide information about old, historical point source impairment from chemicals such as DDT, dieldrin, heptachlor, and endrin. Initial screening of ground water most often focuses on chemicals known to be mobile and capable of entering ground water such as atrazine, picloram, dicamba, and others.

Some Montana agencies will occasionally undertake an initial site evaluation, but as a rule do not usually undertake detailed site sampling projects. Site owners are generally responsible for sampling for point source impairment. Due to the complexity of this type of sampling, the services of experienced environmental consultants should be considered.

Sample Handling

Once ground water samples have been collected, samples should be preserved in the field following sample analysis protocols. Sample preservation that is appropriate to the analytes of interest should be undertaken to minimize biological and chemical

Table 6.1. SDWA and National Pesticide Survey Analytical Methods for pesticides in ground water (Adapted, EPA Guidance Documents, 1992).

Method Number	Title	Comments
504/NPS Method 7	1,2-Dibromoethane (EDB) and 1,2 Dibromo-3-Chlorpropane (DBCP) in Water by Microextraction and Gas Chromatography	EDB and DBCP. Microextraction with hexane (35 mL sample/2 mL hexane). Capillary column, electron capture detector. Confirm with dissimilar column
505	Analysis of Organohalide Pesticides and Commercial Polychlorinated Biphenyl Products in Water by Microextraction and Gas Chromatography	18 pesticides. Microextraction with hexane (35 mL sample/2 mL hexane). Capillary column, electron capture detector. Confirm with alternative column or GC/MS
507/NPS Method 1	Determination of Nitrogen- and Phosphorous-Containing Pesticides in Water by Gas Chromatography with an Electron Capture Detector	39 pesticides. Liquid/liquid extraction with methylene chloride. Capillary column. Confirm with alternate column.
508/NPS Method 2	Determination of Chlorinated Pesticides in Water by Gas Chromatography with an Electron Capture Detector methylene chloride.	25 pesticides. Liquid/liquid extraction with Capillary column. Confirm with alternate column.
515.1/NPS Method 3	Determination of Chlorinated Acids in Water by Gas Chromatography with an Electron Capture Detector	13 pesticides. Hydrolysis with NaOH, methylene chloride wash, liquid/liquid extraction with ethyl ether, derivatize to esters with diazomethane. Optional Florisil cleanup. Capillary column, confirm with alternate column.
525	Determination of Pesticides in Ground Water by High Performance Liquid Chromatography with an Ultraviolet Detector	16+ pesticides. LSE cartridge extraction with methylene chloride elution. Applicable to large number of analytes; can be used for new analytes after obtaining sufficient precision and accuracy data.
NPS Method 4	Determination of Organic Compounds in Drinking Water by liquid-Solid Extraction and Capillary Column Gas Chromatography/Mass Spectrometry	16 pesticides. Liquid/liquid extraction with methylene chloride. Primary and confirmational HPLC columns.
531.1/NPS Method 5	Measurement of N-Methylcarbamoxyloximes and N-Methyl Carbamates in Water by Direct Aqueous Injection HPLC with Post-Column Derivatization	10 pesticides. Uses gradient elution chromatography with NaOH hydrolysis after elution. Primary and confirmational HPLC columns.
NPS Method 6	Determination of Ethylene Thiourea (ETU) in Ground Water by Gas Chromatography with a Nitrogen-Phosphorous Detector	1 pesticide. Liquid chromatography cleanup. Capillary column. Confirm with alternate column.

TABLE 6.2. Analytical methods for selected pesticides (Adapted, EPA Guidance Documents, 1992).

Pesticide	EPA Method
Acifluorfen*	515.1
Aldrin	505, 508, 525, 608, 8081
Ametryn	507, 619
Aminocarb	632
Atraton	507
Atrazine*	525
Azinphos-ethyl	1618
Azinphos-methyl	622, 8141
BarbanMethod	4
Baygon	531.1
Bentazon	515.1
Bromacil*	507
Butachlor	507, 525
Butylate	507
Captafol	1618
Captan*	1618
Carbaryl*	531.1
Carbophenothion	1618
Carbofuran phenol	Method 4
Carboxin*	507
Chloramben*	515.1
Chlordane	508, 608
Chlorfenvinphos	1618
Chloroneb	508
Chlorobenzilate (a)	508, 1618
Chlorothalonil*	508, Method 4
Chlorpropham	507, 632
Chlorpyrifos*	622, 8141
Coumaphos	622, 8141
Crotoxyphos	1618
Cyanazine*	Method 4
Cycloate*	507
2,4-D*	515.1
2,4-DB*	515.1, 615, 8151
Dalapon	515.1
DCPA	508
DCPA acid metabolites	515.1
4,4'-DDD	508, 608, 8081
4,4'-DDE	508, 608, 8081
4,4'-DDT	508, 608, 8081
Demeton	622, 8141
Diallate*	1618
Diazinon (a)*	507, 622, 8141
Dicamba*	515.1, 615, 8151
Dichlofenthion	1618
Dichlone	1618
3,5-Dichlorobenzoic acid	515.1
Dichlorprop	515.1, 615, 8151
Dichlorvos	507, 622, 8141
Dieldrin	505, 508, 525, 608, 8081
Dimethoate*	8141
Dinoseb	515, 615, 8151
Dioxathion	1618
Diphenamid	507
Diquat*	549
Disulfoton*	507, 622, 8141
Disulfoton sulfone	507
Disulfoton sulfoxide	507
Diuron*	632, Method 4
Endosulfan I	508, 608, 8081
Endosulfan II	508, 608, 8081
Endosulfan sulfate	508, 608, 8081
Endothall	548
Endrin	508, 608
Endrin aldehyde	508, 608, 8081
Endrin ketone	1618, 8081
EPN	622, 8141
EPTC*	507
Ethion	1618
Ethoprop	507, 608, 8141
Ethyl parathion	8141
Etridiazole	508
Famphur	8141
Fenamiphos	507
Fenamiphos sulfone	Method 4
Fenamiphos sulfoxide	Method 4
Fenarimol	507
Fensulfothion	622, 8141
Fenthion*	622, 8141
Fluometuron	632, Method 4
Fluridone	507
Glyphosate*	547
HCH-alpha (alpha-BHC)	508, 608, 8081
HCH-beta (beta-BHC)	508, 608, 8081
HCH-delta(a) (delta-BHC)	508, 608, 8081
Hexachlorobenzene	505, 508, 525
Hexazinone*	507, 633
3-Hydroxycarbofuran	531.1
5-Hydroxy Dicamba	515.1
Isodrin	1618, 8081
3-Ketocarbofuran phenol	Method 4
Leptophos	1618, 8081
Lindane*	508, 608
Linuron	632, Method 4
Malathion*	8141
MCPA*	615, 8151
MCPP	615, 8151
Merphos	507, 622, 8141
Methiocarb	531.1, 632
Methomyl	531, 1, 531, 632
Methyl chlorpyrifos	622, 8141
Methyl paraoxon	507
Methyl parathion*	622, 8141
Metolachlor	507, 525
Metribuzin DA*	Method 4
Mevinphos*	507, 622, 8141
Mexacarbate	632
MGK 264	507
Mirex	1618, 8081
Molinate	507
Monuron	632
Naled	622, 8141
Napropamide	507
Neburon	Method 4
Nitrofen	1618
cis-Nonachlor	505
trans-Nonachlor	505, 525
Norflurazon	507
Oxamyl (vydate)	531.1
PCNB*	1618
Pebulate	507
cis-Permethrin	508
trans-Permethrin	508
Phorate*	8141
Phosmet	1618
Picloram*	515.1
Prometon*	507, 619
Prometryn	507, 619
Pronamide(a)	507
Propachlor*	508, 525
Propanil*	Method 4
Propazine	507, 619
Propham	632, Method 4
Propoxur	531, 632
Ronnel	622, 8141
Simazine*	505, 507, 525, 619, Method 1
Simetryn	507
Stirofos	507
Sulfotep	1618, 8141
Sulprofos (Bolstar)	622, 8141
Swep	Method 4
2,4,5-T	515.1, 615
2,3,7,8-TCDD (Dioxin)	513
Tebuthiuron*	507, 8151, Method 4
Terbacil	507
Terbufos(a)	507, 622, 8141
Terbuthylazine	619
Terbutryn	507, 619
Tetrachlorvinphos	8141
Tokuthion (Prothlophos)	8141
Triadimefon*	507
Trichloronate	622, 8141
Tricyclazole	507
Trifluralin*	508, 1618
Vernolate	507

* Indicates the chemical is commonly used in Montana.

degradation of each sample. This may include filtering and the addition of preservatives if appropriate for the analytical methods. Samples should be placed directly into insulated boxes after collection. The main concern in sample packing and shipping is to ensure against breakage and temperature fluctuations. The following sample handling procedures are recommended:

* Ship samples, if necessary, in insulated boxes or coolers.
* Wrap individual glass sample containers in plastic bubble wrap, placed in styrofoam holders, or otherwise package to prevent breakage during shipping.
* Place ice or Gel-Cold packs in each cooler. Gel-Cold packs should not be in direct contact with any of the glass sample containers or the samples may freeze. Ice should be sealed in plastic bags to prevent seepage during transport and to protect sample labels.
* Deliver samples to the laboratory within 24 hours of sample collection and packing.
* Ship all sample tracking paperwork with the shipment and ensure that chain-of-custody procedures have been followed.
* Chain-of-custody procedures are necessary only if the samples are going to be classified as "official."

Coordination with the laboratory concerning frequency and number of samples is important to ensure that sample holding times are not exceeded. The laboratory should be notified *prior* to sample collection to ensure that samples will be processed and analyzed expeditiously.

Sample Custody

As each sample bottle is filled it should be labelled and assigned a sample tracking number. That number should be marked on the sample container and recorded on the collection report form. The information placed on the sample container generally includes:

- date and time of collection,
- well identification,
- pesticides to be analyzed, and
- signature of sampler.

If samples are shipped to a laboratory, a security seal should be placed around the lid of each sample container. Sample custody begins, in all cases, at the time of sample collection by placing the sample with ice in an ice chest, or other appropriate container(s).

Sample Transport

Samples being sent by an overnight carrier to the laboratory must be packaged and shipped in compliance with current U.S. Department of Transportation regulations. Sample chain-of-custody records or shipping records accompanying the shipment should be enclosed in a waterproof plastic bag and taped shut to the underside of the lid of the shipment container.

EPA Methods

Pesticides occur in several chemical compound classes, including organochlorine compounds, triazines, carbamates, carbamothioates, ureas, and phenoxyacids. Because of this chemical variety and the differing needs of its regulatory programs, the U.S. EPA has developed a variety of analytical methods for the detection and measurement of pesticides in water samples. Analytical methods for pesticides have been developed for the Safe Drinking Water Act (SDWA) regulations (500-series methods), the National Pesticide Survey (Methods 1-7), the Clean Water Act wastewater regulations (600-series methods), the Resource Conservation and Recovery Act hazardous waste regulations (8-series methods), and the national Sewage Sludge Survey (Method 1618).

The 500-series drinking water methods and the National Pesticide Survey methods are the most appropriate methods for the analysis of pesticides in ground water and other potential drinking water sources. The 500-series methods are the same as national Pesticide Survey Methods 1 through 3, 5 and 7. These methods employ chromatographic techniques (gas chromatography or high-pressure liquid chromatography) coupled with sample preparation and cleanup methods and specific detectors appropriate for the analytes of interest. Basic information about these methods is presented in Table 6.1. Most are multiresidue methods, allowing the simultaneous measurement of a number of pesticide compounds. Multiresidue methods are cost-effective in that they enable the analyst to screen for a variety of pesticides with a single scan. Such multi-residue methods, however, tend to be less precise for individual analytes and therefore to have higher detection limits than methods concentrating on a single analyte. The 600-series and 8000-series methods are very similar to the 500-series methods and have been evaluated for certain pesticides that are not included in the analyte lists for the former methods.

When selecting an analytical method for a specific pesticide, several factors should be considered. The method detection level (MDL) and practical quantitation limit (PQL) should be appropriate for the objectives of the analysis. For example, the PQL should be at or below the concentration of interest (i.e., the level at which specific actions will be taken). The method also should be selective for the analyte of interest and free of any interference problems from other substances likely to be present in the sample. If the more nonselective methods are used (i.e., gas chromatography [GC] with electron capture detection or nitrogen/phosphorous detection for sample screening), and detections should be confirmed using a different method (i.e., a second GC column with a different polarity). Table 6.2 lists available EPA analytical methods for a number of pesticides.

EPA methods usually contain single-laboratory accuracy and precision data determined for a specific list of compounds. If a method is to be applied to measure compounds for which no such data exist, the laboratory should obtain acceptable accuracy and precision for each added analyte. Method-specific QC requirements also are specified in the procedures and must be followed if accuracy and precision goals are to be met.

Cited References

Montana Department of Agriculture, Laboratory Bureau. 1991. Montana laboratory pesticide quality assurance project plan. Montana Department of Agriculture, Laboratory Bureau, Bozeman, MT.

Montana, State of. 1988. Administrative rules of Montana. Title 16.20.603. State of Montana, Helena, MT.

Montana, State of. 1988. Administrative rules of Montana. Title 16.20.1011. State of Montana, Helena, MT.

Montana, State of. 1991. Montana codes annotated. Title 80-15-202. State of Montana, Helena, MT.

United States Environmental Protection Agency, Office of Ground Water and Drinking Water. July 1992. Definitions for the minimum set of data elements for ground water quality. United States Environmental Protection Agency, United States Government Printing Office, Washington, D.C.

United States Environmental Protection Agency, Office of Pesticide Programs. July 1992. Appendix B: assessment, prevention, monitoring, and response components of pesticide state management plans. *In:* Pesticides state management plan guidance for ground water protection: implementation document for the pesticides and ground water strategy. Draft. United States Environmental Protection Agency, Office of Pesticide Programs, United States Government Printing Office, Washington, D.C.

Chapter 7

Best Management Practices and Plans To Protect Ground Water

Protection of Montana's Ground Water Resources

RAVE

Several years ago, to assist farmers and pesticide applicators reduce the potential for contaminating ground water with pesticides, an aquifer vulnerability scoring system; Relative Aquifer Vulnerability Evaluation (RAVE) was developed. The numeric scoring system helps individuals evaluate pesticide selection for on-site ground water impairment potential. RAVE was designed only as a guidance system and should be integrated with safe and judicious pesticide application that is required in all situations.

Nine of these factors (including depth to ground water, soil texture, cropping practices, pesticide application method, pesticide leaching potential, etc.) have been incorporated into the RAVE score card to help determine the relative vulnerability of ground water to pesticide impairment. A value for most of these factors, as well as the RAVE score sheets, can be obtained through the MDA in Helena or the field offices in Missoula, Great Falls, Bozeman, Billings, and Glasgow.

FARM*A*SYST

The Farm*A*Syst program was developed as a cooperative effort among a large number of midwestern agencies to teach farmers and rural residents in the use of systemic techniques to voluntarily assess water well impairment risks at their farmsteads. It is a proven, effective method of helping users to increase their ability to recognize water pollution risks. It also encourages and facilitates taking appropriate actions to reduce and prevent pollution or to correct problems identified by this program.

The MSUES Water Quality program have been revising the Farm*A*Syst program developed by the USDA Extension Service, Soil Conservation Service and the USEPA, so that it will be suitable for use in Montana. Several of the worksheets that are pertinent to ground water protection at the farmstead level have been revised and will be available through the MSUES in the spring of 1994. Worksheets addressing drinking water well conditions, pesticide and fertilizer storage and handling, and petroleum product storage will allow farmers to assess risks to ground water on individual farm sites.

Utilization of these worksheets plus RAVE allow producers an opportunity to correct problems and plan their farming operations to ensure ground water protection on their farmsteads.

Site conditions, pest outbreaks, crop patterns, and agricultural practices vary widely. This makes it difficult to develop specific recommendations for reducing the risk of pesticide and fertilizer impairment that are appropriate for all situations. There are however, measures that can be implemented which will reduce the likelihood of impairment. They integrate the unique pest, crop and cropping practices which are best suited for a particular site, and thus protect the ground water.

Certified Crop Advisor

The Certified Crop Advisor (CCA) program is a volunrary program to certify minimum standards of knowledge and skills for those who advise farmers in the use of nutrients and pest control measures. The CCA program is a cooperative effort between MDA, MD HES, SCS, MABA and MSUES to ensure that these advisors are qualified to make recommendations for the use of agricultural chemicals that are economically and environmentally sound. These professionals through the exam and continuing education process provide in-the-field expertise on nutrient and pesticide management practices.

Point Source Impairment

Impairment of water resources resulting from activities where the source or point of impairment is readily identifiable is point source. Characteristics include: concentrated in one area, have one to few sources, usually involve large quantities, are associated with dramatic and immediate effects, are relatively simple to monitor, and identify sources or practices (such as effluent disposal practices). Examples include: agricultural activities resulting in chemical spills from mixing and loading, back-siphoning when filling spray tanks, transportation accidents, improper applications, improper storage, and improper disposal.

Nonpoint Source Impairment

Impairment of water resources resulting from activities where the source or point of impairment cannot be readily identified are termed nonpoint source. These types of pollution sources are the result of numerous small quantities that are diffuse and dispersed multiple sources that when taken cumulatively impair water resources. Effects of nonpoint impairment are usually subtle and gradual, making sources or practices contributing to nonpoint pollution difficult to identify. Monitoring of nonpoint impairment is often difficult as well. Examples of nonpoint impairment include: wind and water erosion, saline seeps, normal agricultural chemical and fertilizer use, land disposal of organic materials (manure, sewage sludge), and cropping systems.

Best Management Practices

Through technical assistance, incentives, education and best management practices (BMPs) much of the current pollution, both point and nonpoint sources, can be reduced or eliminated. Best management practices are methods, measures, procedures or practices used to control or reduce point and nonpoint source pollution (Thomas, 1990). Best management practices can be in the form of control measures, operation/maintenance procedure changes, and implementation of integrated management techniques. These BMPs provide a framework for integrated nutrient and pesticide management. Some combination of these BMPs should be tailored for the unique soils, climatic conditions, management, products, cropping systems, and related features unique to each field. As new technologies develop, new BMPs will be available to efficiently and effectively manage nutrients and pesticides.

Integrated Pest Management

Effective pest management strategies integrate biological, cultural and chemical control mechanisms. An integrated pest management program (IPM) when added to crop management strategies, will maximize fertilizer and water use efficiency and protect ground and surface water. Integrated pest management uses a systems approach to prevent and reduce pest damage to tolerable levels through an integrated process using natural predators and parasites, genetically resistant hosts, environmental modifications, and when necessary and appropriate, pesticides. Decisions are based on economic thresholds and not the mere presence of a pest. The implementation of an IPM program does not remove pesticides as an option, or guarantee a reduction in pesticide use, it only suggests appropriate use of pesticides and other control options. None of these control measures alone can solve all problems, and each has benefits and drawbacks. The purpose of an IPM system is to evaluate the costs, risks and benefits to a particular control strategy, including ground water protection. The IPM program must consider potential interactions between key pests, their natural enemies, other actual or potential pests, and other living and non-living factors. The methods chosen must be based on ongoing monitoring and evaluation of the system. In an IPM program, pest control does not necessarily translate into complete eradication, but the suppression of pest populations below the level at which they cause unacceptable damage.

The proper combination of BMPs in agricultural production systems will provide the ultimate protection and maintenance of both ground and surface water. However, some practices identified in this section which protect surface waters, may contribute to ground water impairment by infiltration and deep percolation of dissolved pollutants, if excess water is applied and vice versa. Many factors need to be considered to ensure the best combination of practices. These include current land use, type of crop and cropping sequence, distance from open water, irrigation system, if applicable, and soil type.

The first and most important step is to identify the pest and the extent of the problem before determining the need for and selection of a pesticide or other control measure. Choose control strategies that are:

* least damaging to ground water and other parts of the environment,
* least disruptive of natural controls,
* least hazardous to human health,
* least toxic to non-target organisms,
* most likely to produce a prolonged reduction in the environment's ability to support the pest,
* most likely to be carried out reasonably and effectively, and
* most cost-effective in the long run (Olkowski and Daar, 1988).

All pesticide selections should be based on characteristics such as formulation, mode of application, solubility, toxicity, degradation, and adsorption. Application site characteristics such as soil type, geology, depth to water table, proximity to surface water,

topography and climate that minimize the potential for pollution of ground and surface water need to be considered.

Once these factors have been determined, combinations of practices can be selected. For irrigated lands consider irrigation systems, (i.e., flood vs. sprinkler) and proper irrigation water management to reduce excess percolation and runoff. Other practices which help to reduce runoff (if applied properly), are cropping sequence, conservation tillage, cover and green manure crops, field borders, contour stripcropping, mulching, grassed waterways, and crop residue use. Permanent vegetative covers such as pasture and hayland planting will also reduce runoff.

Every crop has pests that will affect crop yield and quality. Planning throughout the cropping sequence is an essential component to a successful IPM program. A good IPM program incorporates problem identification, control strategies, economic analysis, implementation and careful evaluation of the effectiveness of all control measures.

The implementation of IPM is essential for ground water protection. IPM integrates the complete system and uses of naturally occurring pest controls. The intent is to target and sometimes reduce overall pesticide use. These controls include the weather, disease agents, predators, and parasites. Also used are various biological, physical and chemical control, and habitat modification techniques.

Field Scouting

Good crop management decisions are based on accurate information about field conditions. Consistent and methodical field monitoring lays the groundwork for an effective pest management program. Field scouting can maximize production efficiency if the producer or consultant knows what to look for, when to look and how to use the information acquired. Examples of management decisions that can be made based on field scouting results include:

* improving pesticide application timing to maximize control and minimize crop injury,
* rotating non-host crops (such as alfalfa after wheat) before disease problems cause significant yield reduction,
* planting a resistant variety (such as sawfly-resistant wheat), and
* using a seed treatment (such as for wireworm control).

Accurate records are an essential part of pest management and are valuable when investigating pesticide performance problems. Collecting and evaluating pertinent field information helps identify and solve crop management problems. The result is prevention or reduction of crop losses and maximization of production efficiency, thereby increasing profits.

Field scouting depends mostly on personal observation skills. A good way to do this is to relate scouting to taking a series of mental pictures. The field scout should assume the role of a camera to observe and record what is seen in the field. The first "picture" should be a wide-angle view of the entire field. This picture provides an impression of the field and identifies specific areas that need further checking. This first look often reveals mechanical problems such as fertilizer skips, windrow effects and tillage patterns. These problems often are seen as field variations having straight and definite lines of demarcation. "Getting the big picture" should also be done at each sample site because sun angles and terrain can aid in showing problems that may have been hidden at a former location.

The next picture should be similar to a family portrait, and is focused on a specific area, 6 to 15 feet away. This picture views a group of individual plants, and shows their relationship to the rest of the immediate area. Color, variation in height, invader plants, dying or stunted plants, white heads and skips in the row are possible observations. They could indicate nutrient deficiencies, hail injury, herbicide damage or possible insect, disease or weed problems.

The last picture should be a close-up view. This shows specifically what is wrong with the plants. To do this, plants in an area of about 1 square yard should be observed individually. Aboveground parts of some of these plants should be examined carefully, preferably with a hand lens. Below-ground parts should also be examined. A digging tool can be used to lift plants from the ground, so the roots are still intact. Pest problems can often be identified at this time, and other types of injury, weed species present and the crop's stage of development can also be recorded.

Walking fields is by far the best method of field scouting. Some people use a four-wheeler, but they must go slowly and stop at each site to do a thorough analyses. Looking out the window of a pickup truck at 45 mph does *not* permit one to see details in the growing crop! Problems that can be spotted this way usually have gone too far to be corrected.

As a general rule, fields should be scouted weekly. Although the incidence of pests may not require that all fields be checked each week, some fields should be checked every few days when infestations are approaching economic threshold levels. If no symptoms or signs of pests are present, producers need not waste time with detailed counts. With practice, producers will soon become efficient at scouting pest populations and making integrated crop management decisions based on the pest information collected.

Biological Control

Biological control is the use of organisms or biological agents to control a weed, insect or disease problem. These may include bacteria, fungi, viruses, plants, animals, and beneficial insects. Many biological control agents are not feasible for use on a large scale in Montana. There are numerous examples, however, of successful biological control programs such as leafy spurge control with sheep and flea beetles, insects which attack knapweed, smut disease which attacks cheatgrass, and rust which attacks wild oats. In the future, biological control methods as they become available will be more fully integrated into production farming systems. Allelopathic effects of one plant to prevent or suppress the development of another plant due to chemical inhibitors may also provide future control options with further research.

Cultural Control

Many routine agronomic decisions influence a crop's ability to compete with pests. For example, crop rotation is one of the most important factors in disrupting pest cycles. Crop rotation will potentially improve weed control, reduce herbicide inputs for crops in the rotation and decrease the likelihood of the same herbicides being used in the same field year after year. With the diversity present in rotations, both crop and weed species that could serve as hosts for insects are decreased. Pathogen carryover or buildup in soil or crop residues can also be minimized with crop selection and rotations (Alberta Agriculture, 1988). Planting forage crops helps control annual weeds. Annual crops help to control perennial weeds. Legumes integrated into crop rotations will add N to the system, control surface erosion and increase soil organic matter. More intensive cropping and the use of legumes in a crop rotation system can also improve soil fertility and water use efficiency by decreasing the amount of residual water remaining in the soil profile. Monoculture cropping systems favor the establishment of high populations of weeds, insects and diseases.

Mechanical tillage and pre/post-emergent cultivation can be used to directly control weeds and disrupt insect populations by removing weed reservoirs and covering eggs and crop residues with soil. Early fall tillage, for example, will kill more wheat stem sawfly larvae than spring tillage. Tillage practices can supplement or replace chemical means of weed control during seedbed preparation, fallowing and row cultivation operations. Mowing of weeds prior to seed set and timely harvest operations will reduce weed populations. Under rangeland conditions, controlled grazing can minimize the spread of weeds. Residue management can also avoid the buildup of plant pathogens.

A critical step towards pest control is selection of a particular crop cultivar that is less susceptible to the diseases and insects present in a geographic region. The Montana State University Agricultural Experiment Station and Extension Service annually publish variety recommendation lists for regions within Montana. Altering planting or harvesting dates, row spacing and seeding rate can also reduce the impact of certain pests, however, there may be an associated reduction in yield.

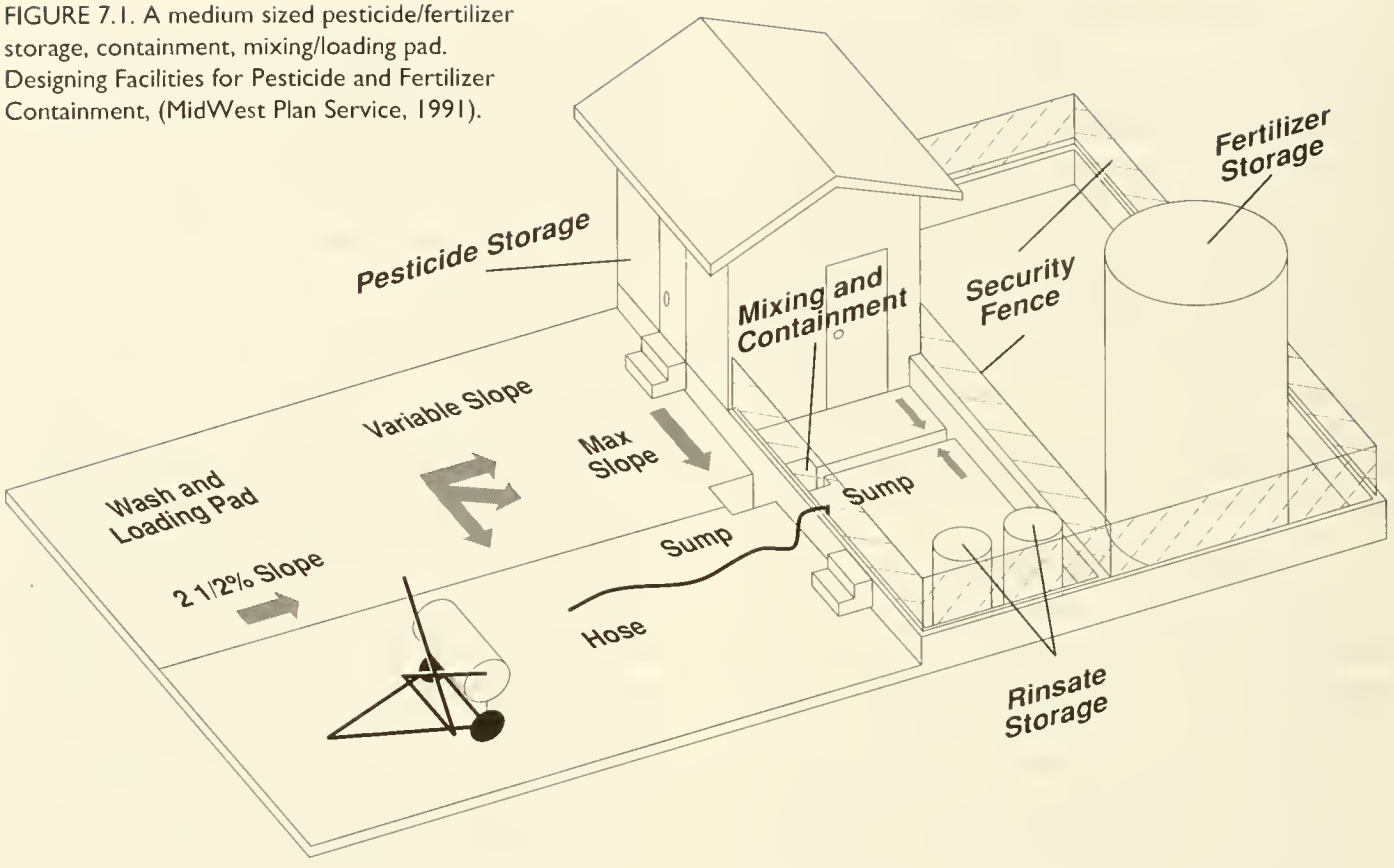
Water management under both dryland and irrigated conditions can influence pest populations and cultural and chemical control strategies. Dryland farming practices use stored soil water and growing season precipitation. Make crop selection and yield potential estimates early in the agronomic decision-making process. These decisions with an integrated system influence for example, nutrient management which ultimately impacts the ability of a crop to efficiently use water for growth. This minimizes the net loss of water and potential downward movement of soluble nutrients and pesticides into ground water. Perennial forages integrated into a small grain cropping system as part of a rotation; particularly in place of fallow systems, prevents downward movement of water and potential contaminants. Under the summer fallow system, there is potential to lose nitrate and some pesticides through the inefficient use of stored moisture and precipitation.

Under irrigated cropping systems, the rate, timing and amount of applied water is controlled, so that crop water requirements are met while minimizing surface runoff and leaching losses. Irrigation rate and frequency should be determined by crop needs and soil conditions. Soil moisture should be monitored to determine when irrigation water is needed to eliminate crop stress. When the soil is irrigated, the volume applied should not exceed the water holding capacity of the soil in the root zone. When excessive amounts of water are applied to a field prior to pesticide breakdown, plant uptake, or soil adsorption, leaching of mobile pesticides is likely to occur. Surface runoff should also be controlled to prevent soil erosion and loss of nutrients and pesticides in runoff. Timing of irrigation water application should also be controlled, so that water is not applied when pesticides are susceptible to loss.

Chemical Control

Pesticides are an important tool in IPM programs. They are effective against a wide variety of pests, quick acting and provide an economical control method when the pest problem reaches threshold levels. When selecting a pesticide, consider the pesticide characteristics (solubility, adsorption and breakdown rate) that influence its potential for water impairment, in addition to the effectiveness and cost.

FIGURE 7.1. A medium sized pesticide/fertilizer storage, containment, mixing/loading pad. Designing Facilities for Pesticide and Fertilizer Containment, (MidWest Plan Service, 1991).



Wherever possible, a pesticide with the lowest leaching potential should be selected. In addition, spot treatment should be considered if the area of infestation is confined to a small area or the site is susceptible to leaching or surface runoff. Pesticide use in particularly vulnerable locations such as in riparian areas, wetlands and significant recharge areas should be avoided.

Physical features of the site influence a site's susceptibility to impairment. These include soil characteristics, depth to an aquifer, location of surface waters and depth to water table. Read and follow all label directions and comply with all federal and state laws regulating pesticide use, storage and disposal. All equipment should be properly calibrated. The time of pesticide application for maximum effectiveness should be integrated with irrigation scheduling and climatic conditions, so that the chance of leaching is minimized. Mixing and loading sites and equipment rinsing areas should be designed for protection of all water resources. It is essential to avoid pesticide spills and prevent back-siphoning into wells.

Pesticide Management

Application of pesticides according to label directions will help prevent impairment of ground water. Applicators should pay special attention to application rates and cautions or instructions intended to minimize water impairment. Impairment of ground water can occur when a pesticide is applied according to label directions. This is not normally the case, but when conditions such as shallow ground watet or coarse textured soils are present in areas of a pesticide application, it can occur. To prevent this, an applicator must be aware of the circumstances that can enhance the ability of a pesticide to move into ground water. If conditions exist that permit a pesticide to enter ground water, alternative pest management techniques should be considered. Pesticides should be applied at the minimum application rates needed to control the target pest. The old adage of "one is good, two is better" does not apply to pesticides! Some pesticides have soil pH or soil type restrictions listed on the label. Do not use these pesticides in areas where soil conditions do not match those specified on the label. Other pesticides that are highly or moderately soluble in water may

have statements prohibiting application in areas where shallow ground water is present.

Most nonpoint pesticide impairment problems can be *prevented* by being aware of the factors that are conducive to pesticide leachability.

The MDA provides information, training and testing, licensing and issuance of special permits for pesticide applicators. All applicators in Montana should be competent applying pesticides according to label instructions and warnings. However, there are "precautions" that pesticide applicators can take to enhance effectiveness without causing pollution.

Integrated pest management systems are developed to utilize the most appropriate means of pest control. IPM includes cultural, mechanical, biological and chemical control methods, crop rotation, and varietal resistance. Crop rotation can also provide effective weed, insect, and disease control.

Specific agricultural chemical products may be restricted within specific geographic areas when:

* the level of an agricultural chemical in ground water is at 50 percent of the mcl,
* a noticeable trend of increased presence of the agricultural chemical is detected in ground water at the mcl,
* the agricultural chemical has been determined to have migrated in the ground water from the point of detection,
* the EPA proposes to suspend or cancel registration of an agricultural chemical, and/or
* the agricultural chemical (that is being applied to areas underlain by ground water that is vulnerable to impairment) possesses or is suspected of possessing properties that would indicate its potential to migrate to the ground water.

Storage Sites

The MDA is in the process of developing rules for mixing/loading and storage facilities (MLS). The proposed rules would require any person who operates a mixing/loading site (M/L), after the adoption of the MLS rules, to comply with the requirements of the proposed rules within three years of their adoption. Any person who operates a storage facility that is established before the adoption of the rules would, within four years, be required to comply with the requirements for a pesticide storage facility (Figure 7.1).

The MDA will be working on rules for mixing and loading sites that may contain the following rules.

1. Mixing and loading sites must be provided with a means of containment that is elevated above the surrounding area and constructed for that intended purpose.
2. The M/L sites should be constructed to contain pesticides and rinsates, and other materials spilled or deposited during mixing, loading, or washing activities.
3. If the M/L facility is under a roof to protect it from precipitation, the facility should be able to contain the displaced volume of any storage tank at the M/L facility such as a tank for mixing water or a rinsate tank.
4. It should be able to contain 110% of the largest container involved in the M/L process.
5. If the M/L facility is not under a roof, to protect it from precipitation, the facility must be able to contain the volume of a 4-inch rain storm, plus any displaced volumes, and at least 125% of the largest container located on the facility.

All pesticide releases occurring in or on a M/L area or a pesticide storage facility should be recovered as soon as possible and must be properly used, stored or disposed. Use and storage must be according to pesticide label instruction. Disposal must be according to label directions and must also comply with local, state and federal regulations. The MDA must be notified immediately of all releases that are outside the containment area.

The MDA requires that any person who stores and handles pesticide containers to:

1. inspect each container annually,
2. rotate the stock (use oldest first),
3. keep an up to date inventory,
4. keep Material Safety Data Sheets (MSDS) available for all pesticides being stored on site, and
5. store pesticides only in their original containers.

Mixing and loading activities should provide a means of containment which prevents runoff from or to the surrounding area and which is constructed for the intended purpose following standard engineering practices. These operations shall be carried out in a manner that prevents escape of discharges which may result in adverse effects on the environment.

Pesticide spills do happen, but their impact is lessened through proper storage and handling procedures. Storage facilities should be

posted to warn people of its contents and locked to prevent entry by unauthorized persons. Empty containers need to be properly stored until they can be disposed. Storage facilities should be located on level ground and where drainage will not wash into ponds, streams or lakes. The buildings should be fire resistant, have a cement floor, ample room to move around in, and good ventilation.

Store different types of pesticides separately within the storage area to prevent one type of pesticide from contaminating another and to prevent accidental use of the wrong pesticide. All mixing/loading and storage facilities should have an Emergency and Discharge Response Plan (EDRP) and a current inventory. This plan must be complete; so that someone remotely familiar with the facility would be able to respond to a discharge using the information contained in the plan. An ERP should contain, but not be limited to, the telephone numbers of the MDA, MDHES, Local Fire Departments, Disaster and Emergency Services, Sheriff Department and, if applicable, City Police Department.

If there is a well near the storage site, precautions must be taken to insure that impairment from mixing and loading operations will not occur. To prevent impairment of water resources during mixing and loading, care must be taken to prevent back siphoning of product into hoses. This can be accomplished by providing; 1) an air gap in the line, 2) one to two anti-siphoning devices in the line, 3) a separate tank and pump, and 4) a good well head seal. If a spill does occur, clean it up *immediately* and notify the proper authorities.

Applicators should control their pesticide inventory, mix only what is necessary to control the pests involved and use all of the diluted product generated. Pesticide waste disposal can be time-consuming and expensive; it must also conform to specific regulations. Because of the possible adverse impacts on cropland, ground water, and other concerns, disposal methods that reduce the amount of wastes generated are the most effective and cost-efficient. The best alternative for disposing of excess pesticides is recycling or reuse. All pesticides and rinsates must be used in accordance with label directions.

Mixing/Loading Sites

Spills and poor management at mixing/loading facilities are one source of potential pollution identified through the *source of contamination inventory stage* for the wellhead protection program. Proper storage, application, and disposal of these chemicals aid in reducing potential impairment of ground water.

The most effective approach to protecting wells that provide drinking water to farms would be to move all M/L activities away from the wells. Chemicals could be mixed/loaded on-site by hauling water in a separate tank (nurse tank) to the field. This approach would also prevent any back-siphoning that might occur when filling the sprayers. After applying the chemicals to the crop, the sprayers should be rinsed in the field and the rinsate sprayed on the crop. The benefit of on-site M/L is that one site is not continuously exposed to the chemicals. If a spill occurred it would be a unique event with a remote chance of multiple spills occurring at a single site.

States are beginning to require that commercial storage and mixing of pesticides be confined to watertight pads. Spills and rinsate can then be contained and collected for reuse or proper disposal. Recycling pesticide tank residues and rinse water helps to reduce the amount of pesticide needed. When used in this manner, these materials are no longer considered hazardous wastes. *The Small Quantity Generator's Handbook For Managing RCRA Wastes-Pesticide Application* contains many management practices that are used today to prevent impairment caused by agricultural chemicals at these sites.

The MDA also recommends that all employers train their people in the safe use and handling of pesticides. Correct calibration is essential to ensure the equipment is applying the desired amount of pesticide uniformly over the target area. The MDA will continue to include programs on calibration in the initial training sessions as part of its training program.

Disposal of Pesticides

Some people feel that the only time there is danger when handling pesticides is during the application or the M/L operation. An unrinsed container may still have several ounces left in it and can still pose a safety or health threat. Care should be exercised at ALL TIMES where agrichemicals are present.

Pesticides and pesticide containers being disposed of are considered solid or hazardous wastes. Rinse water that is disposed of and not reused is also a solid or hazardous waste. The MDHES-Solid and Hazardous Waste Bureau regulates hazardous wastes. Sections 3.0 and 4.0 of *The Small Quantity Generator's Handbook For Managing RCRA Wastes-Pesticide Application* outline the appropriate waste management regulations to be followed. A person who generates pesticides that have been determined to be hazardous wastes, should coordinate with either a private consultant or with the appropriate state agencies in order to properly dispose of these materials. Specific pesticide wastes should not be mixed with other pesticides wastes. Pesticide containers should be triple rinsed to remove pesticide residues and disposed of properly. Containers that have been triple rinsed may be disposed of in a licensed Class II sanitary landfill. Most rinsates should be used as a diluent in future applications of the same pesticides.

Disposal of pesticides must be in compliance with 1) the label, 2) solid and hazardous waste laws, and 3) state and federal pesticide laws.

Pesticide Container Disposal Project

In 1992, the MDA assisted in a pesticide container disposal project conducted by the Montana Agricultural Business Association (MABA). They are currently working on a permanent pesticide container recycling program for Montana. The proposed program will provide recycling opportunities for properly triple rinsed and/or power-rinsed plastic pesticide containers from private as well as commercial applicators.

The 1993 legislature approved an amendment to the Montana Pesticides Act that authorizes the MDA to establish a waste pesticide and pesticide container collection, disposal, and recycling program. The MDA will promulgate rules that will define the scope of the program. The actual collection and disposal operation will likely be contracted out with the MDA designating the types of waste pesticides or pesticide containers that will not be collected for disposal or recycling under this program. The program will be funded by licenses, permits and special fees designated in the Act. Pesticide applicators, dealers and operators who participate in the waste pesticide and pesticide container collection, disposal, and recycling program and who are subject to a license or permit fee will receive a credit against the fees levied. It is anticipated that this program will become operational in 1994.

Agricultural Chemical Spills and Accidents

At least one person at a site where agricultural chemicals are being manufactured, stored or used should be able to initiate and coordinate emergency response activities in the event there is a spill or accidental release. All employees at these sites should be familiar with waste handling and emergency response procedures.

The initial response to an agricultural chemical spill should be to *contain the spill.* Next, the appropriate persons or agencies should be notified of the spill. The MDA should be notified immediately at **444-2944** by the responsible person of an agricultural chemical spill. The Montana Hazardous Materials Emergency Response System should also be contacted immediately at **1-800-426-9440** or **1-406-444-6911**. The Disaster Emergency Service will then notify the appropriate agency of the spill. The National Response Center should be contacted at **1-800-424-8802** if a spill occurs that threatens human health or has reached surface water.

The spill report should include the private or commercial owner's name and address, date, time, location, type of accident, quantity and type of chemical involved in the spill, estimated quantity and condition of recovered chemical, and any injuries. The final phase in an emergency response plan is to implement clean up procedures to remove the agricultural chemical from surface and/or ground water and to remove any contaminated materials or soil from the site.

Wellhead Protection

Nonpoint sources of ground water impairment that implement BMPs are in compliance with water quality standards. However, cropland on which pesticides and fertilizers are applied may lie within a wellhead protection delineation zone for a public water supply. In 1991, the USDA made ground water protection a criteria for nominating new lands for inclusion in the Conservation Reserve Program. Agricultural lands within a certified Wellhead Protection Area would be given the highest priority, thus creating an incentive to protect public drinking water supplies from agricultural chemicals. The proposed Montana Wellhead Protection Program is a voluntary program to protect ground water used for public drinking supplies and from contaminants which may have adverse effects on human health. It is coordinated by the MDHES.

Nutrient Management

Nutrient management integrates all potential sources of nutrients with a cropping system, yield potential, site characteristics, water management, climatic conditions, and management intensity. Nutrient additions should consider the immediate effect on crop yield and quality in addition to the long-term impact on soil productivity, soil organic matter and water quality. Optimum nutrient management practices provide the correct quantity of nutrients at the best time and location possible, so they are used efficiently.

The major sources of nitrate impairment are: septic systems, livestock feedlots and barnyards, organic matter mineralization, natural resources, and fertilizers. The degree of nitrate impairment from a septic system depends on the density of the system, depth to the aquifer, the amount of mixing with ground water, the direction and rate of ground water movement, and nitrate concentration in the ground water up gradient from a residence.

Livestock feedlots and barnyards have increased nitrate leaching potential due to the confined areas which concentrate animal wastes. Properly composted manure increases the nutrient concentration and reduces the overall volume of material and subsequent number of application trips to the field. Nitrogen is

released more slowly, since most of N is in the organic form. Runoff containing high nitrate enriched with phosphorus from manure could contaminate both surface and ground water adjacent to the feedlots and barnyard.

Conditions conducive to impairment problems by nitrogen include shallow ground water, coarse-textured soils, high organic matter levels, high soil permeability and excess water (precipitation, irrigation). The rate and timing of nitrogen fertilizer application is the most important nutrient management practice affecting nitrate-nitrogen contributions to ground water. For a given yield, crop recovery of nitrogen in the soil decreases with increasing application rates. Residual or unrecovered nitrogen can leach to ground water. Cropping systems that increase soil organic matter promote more efficient use of N regardless of the form applied and potentially increase pesticide adsorption (Rasmussen, 1989). Organic matter can be increased through more intensive cropping, reducing summer fallow, integration of green manure and by a reduction in tillage. All sources of nitrogen—organic matter, fertilizer, manure, legumes, irrigation water, and precipitation must be considered in developing a nutrient management program that includes ground water protection.

Water quality concerns with phosphorus management relate primarily to surface waters. Off-site movement of phosphorus can contribute to the eutrophication of surface waters—a process where the water is so enriched with dissolved nutrients that the oxygen level in the water is reduced. Ground water impairment from phosphorus sources is not a real concern in Montana, since phosphorus readily artaches to soil particles on the surface and will not leach in this semi-arid environment.

Soil Testing

Nutrient management begins with a soil test to estimate the nutrient-supplying capacity of the soil. Since soils are extremely variable, soil samples must be representative of a field, portion of a field, or a problem area (Soil Sampling, MONTGUIDE 8602AG). At least 20 cores should be obtained from an area no larger than 100 acres for this representative soil sample. Soil samples should be collected to a depth of at least two feet and preferably to four feet for nitrate-nitrogen analysis.

Other fertility characteristics (pH, organic matter, salts, phosphorus, potassium) are determined in the top six inches of the soil profile. To account for seasonal variations, soil samples should be collected at approximately the same time each year. Representative soil samples should be collected as closely as possible to seeding for accurate determination of soil nutrient status for the upcoming growing season. Soils should be retested as often as necessary to determine the influence of cultural practices and crop production on soil chemical properties and nutrient availability.

Soil samples should be taken for three to four consecutive years to establish baseline organic matter, nitrate-nitrogen, phosphorus, and potassium levels. Following this period, nitrate-nitrogen concentrations should be determined on an annual basis. Organic matter, phosphorus and potassium determinations can then be determined every three to four years. Once a sample is taken, the integrity of the sample should be maintained to ensure that it accurately reflects field conditions and that no contaminants are introduced prior to laboratory analysis. *Soil Testing Laboratories - A Summary of Services Available to Montana Farmers (Extension Bulletin 1349)* describes soil testing analytical services currently available from commercial laboratories.

Fertilizer Recommendations

Fertilizer recommendations must be crop- and site-specific; integrating past experiences and specific differences in soils, climate, management and soil test values to adjust the general guidelines presented in *Fertilizer Guidelines for Montana (Extension Bulletin 104)*. The actual rate of fertilizer nitrogen application should consider all of the potential sources. Realistic yield potentials estimated from historical yields, stored soil water, and precipitation probabilities are used to accurately determine optimum nitrogen application rates. Grain yield and water relationships are presented in *Grain Yields Related to Stored Soil Water and Growing Season Rainfall (Agricultural Experiment Station Special Report 35)*. Accurate climatic and historical yield records should be maintained to determine realistic yield potentials.

Nitrogen fertilizer applications should be timed and placed to correspond with crop demand. The greater the time between application and crop use of nitrogen, the greater the potential for loss of nitrogen to ground water. With most crops, the demand for nitrogen and phosphorus is substantial during the early part of the growing season, just for vegetative production. Since the yield of many crops is determined during this early growth period, nutrient deficiencies will limit production if not present in adequate amounts. Surface applications of manure, urea or nitrogen solutions should be incorporated, if possible, and appropriate for the time of year to avoid volatilization losses. Fall application of nitrogen, particularly on coarse-textured soils, should be avoided since fall and winter precipitation may increase leaching losses. Application of nitrogen fertilizer and manure to snow-covered and frozen soils should consider the potential for surface runoff following rapid snow melt.

Best Management Practice Summaries

Pesticide Management

- ✓ Provide an optimum environment for a healthy crop through resistant variety selection, planting date and planting depth, selection of a competitive crop, residue and nutrient management, and other related agronomic factors. Renovate pasture and forages to stimulate a healthy crop.
- ✓ Use crop rotation, crop selection, weed and disease-free seed, trap crops, resistant varieties, mechanical, cultural, and biological control measures, when viable, to decrease pesticide use and avoid resistance.
- ✓ Integrate conservation tillage practices to decrease off-site pesticide loss with sediment.
- ✓ Use contour farming, filter strips, field borders, cover crops and field windbreaks to decrease sediment losses from wind and water erosion.
- ✓ Consider intercropping a legume with small grains to out compete weeds. A small grain interseeded with a slow starting perennial forage can control weeds.
- ✓ Use integrated crop and pest management (IPM) strategies which combine chemical control with other pest management practices.
- ✓ Utilize and mainrain natural predators and parasites whenever possible. Promote diversity through the establishment and protection of undisturbed areas to encourage populations of beneficial predators, parasitic insects and insect disease organisms.
- ✓ Scout fields regularly to identify the pest(s), pest location(s), and severity of infestation.
- ✓ Consider soil characteristics and geology into pesticide control strategies.
- ✓ Select pesticides with the least potential for leaching or runoff on susceptible sites.
- ✓ Only trained individuals should apply pesticides.
- ✓ Consider spot applications of pesticides rather than whole field applications. Hand pull small infestations of weeds. Band apply pesticides over the crop row rather than the whole field to reduce the total amount applied.
- ✓ Reduce the quantity of pesticides used where appropriate.
- ✓ Use selective pesticides at the correct time to preserve natural controls.
- ✓ Read and follow pesticide label directions concerning proper application rate, timing and environmental hazards.
- ✓ Calibrate application equipment accurately to deliver the correct amount of pesticide.
- ✓ Check equipment for leaks and malfunctions before, during and after an application.
- ✓ All field equipment should be cleared of plant materials to avoid spreading weed seeds and diseases.
- ✓ Avoid using weed-contaminared manure.
- ✓ Purchase, measure and mix only the quantity of pesticide that will be used in a single growing season.
- ✓ Use an antiback-siphoning device when mixing a pesticide. When filling a spray tank, the end of the fill hose should remain above the water level in the tank.
- ✓ Avoid mixing chemicals near springs or wells (both active and abandoned) by using a long hose so that mixing occurs at least 100 feet *from* the water source. Never mix pesticides directly uphill from any water supply. Use surface diversion practices and erosion control measures for additional protection. Rotate the location of mixing and loading sites.
- ✓ Properly dispose of pesticide containers and pesticides.
- ✓ Consider environmental sensitivity (soil type, hydrology, and runoff) when selecting a location for storage and M/L facilities.
- ✓ Triple rinse or power rinse empty containers. Pour the rinsate into the spray tank for use in treating a crop or site specified on the label.
- ✓ Never drain excess pesticide or pesticide mixtures onto the soil or into sewers, drains, septic systems, ditches, streams, ponds or lakes.
- ✓ Store pesticides in a locked building on an impermeable surface away from water sources.

- ✓ Integrate irrigation events and weather into the pesticide application decision by delaying application if heavy or sustained rain or wind is forecast.
- ✓ Plan pesticide use carefully and evaluate all risks. Avoid a pesticide application when conditions are most likely to promote leaching.
- ✓ Follow requirements of specific management plans.

Nutrient Management

- ✓ Select a realistic yield potential that matches soil productivity with available water and growing season precipitation or irrigation events.
- ✓ Soil test before fertilizing or planting. Consider a soil test at the end of the growing season to fine tune nitrogen management.
- ✓ Take deep soil samples to determine residual nitrate-nitrogen.
- ✓ Probe the soil for stored soil moisture in the spring. If ample stored moisture is present, consider planting a crop in a rotation rather than fallowing (flexible cropping).
- ✓ Allow credits for manure, sludge, organic matter, irrigation water and legume nutrient contributions.
- ✓ Analyze a representative sample of organic materials (manure, sludge) for their nutrient content. Account for pre-application losses during storage due to handling and spreading.
- ✓ The application rate should be based on a soil test and include the mineralization rate of the manure or sludge. Consider applications throughout the year to avoid storage losses and improve crop nutrient use. Apply uniformly by mixing as much as practical and by using good equipment. Directly inject or incorporate promptly after application.
- ✓ Avoid application on steep slopes during the rainy season and avoid spreading manure on frozen ground. Apply organic materials on sandy soils as close as possible to planting to minimize leaching.
- ✓ Apply only as much nitrogen and phosphorus as required on the basis of a soil test, crop, yield potential and management intensity.
- ✓ Consider soil texture, water holding capacity, slope and other physical/chemical features that impact the leaching and runoff potential of residual and applied nutrients.
- ✓ Plan nitrogen applications to correspond with crop demand. Consider split nitrogen applications, nitrogen sources and the use of nitrification inhibitors.
- ✓ Incorporate plant nitrate tissue testing to "spoon-feed" N to the crop.
- ✓ Consider matching residual fertility levels in the soil with variable yield potentials through the application of variable fertilizer rates, rather than a uniform rate for the whole field.
- ✓ Do not apply nitrogen materials in the fall on coarse textured soils or shallow soils over fractured bedrock.
- ✓ Consider band or broadcast/incorporate applications of phosphorus to avoid erosion losses.
- ✓ Properly calibrate fertilizer applicator equipment to deliver the desired amount of fertilizer material.
- ✓ Manage fertigation systems carefully.
- ✓ Schedule irrigation to minimize leaching and meet crop water requirements. Where applicable, use contour tillage, terraces, sediment ponds and other methods to trap runoff.
- ✓ Diversify crop rotations to include crops that can utilize residual nitrogen, and stored soil water particularly at deeper depths.
- ✓ Blend and store fertilizers and other nutrient sources away from water sources.
- ✓ Consider vegetative buffer strips to separate cropped areas from environmentally sensitive areas.
- ✓ Control soil erosion and concurrent off-site movement of nutrients, particularly phosphorus, through proper management of crop residues, maintenance of vegetation on ditch banks and in drainage channels. Slope field roads toward the field and consider permanent plant cover on roads. Use windbreaks and conservation tillage to control wind erosion.

Wellhead Protection

- ✓ Protect wells from back-siphoning.
- ✓ Inspect and maintain all wells in good condition (i.e., capped, no rodent damage, no cracks, broken seals or other degradation).
- ✓ Do not apply chemicals within the vicinity of a well.

- ✓ Properly abandon all wells that are not in use.
- ✓ Elevate or curb wells to prevent spills or surface runoff from entering the wells.
- ✓ Protect water lines from back-siphoning by use of air gaps, a back flow check valve or other mechanism.
- ✓ Conduct a Farm*A*Syst assessment of your farmstead.

Storage Sites

- ✓ Analyze water samples from on-site wells within the past year for the type of chemicals handled at the facility.
- ✓ Never store agricultural chemicals below grade or in basements.
- ✓ Store all agricultural chemicals away from all sources of water.
- ✓ Store an agricultural chemical with flammable or combustible properties away from open flames, separated from other chemicals and properly labeled.
- ✓ Know the location of the private and public water supply wells nearest to your facility.
- ✓ Know the depth to ground water and to the aquifer.
- ✓ Know the general direction of ground water flow beneath your facility.
- ✓ Have adequate lighting in all product storage and handling areas.
- ✓ Locate all pipes, valves and hoses within a containment structure.
- ✓ Inspect the storage site regularly for cracks or leaks.
- ✓ Contain all products under a roof.
- ✓ Divert rainwater from contact with the product.
- ✓ Store agricultural chemicals in a separate area to prevent possible impairment of animal feed, grain, fertilizer and other materials.
- ✓ Keep pesticide containers closed except during transfer operations.
- ✓ Consider environmental sensitivity (soil type, depth to ground water) in locating storage and M/L sites.

Mixing/Loading Sites

- ✓ Consider an on-site containment area at mixing/loading sites. A containment pad helps prevent widespread impairment if a spill were to occur.
- ✓ Position all mixing/loading equipment in the containment area or on a containment pad.
- ✓ Collect rinsate and pump into rinsate storage tanks.
- ✓ Do not mix at the wellhead, near monitoring wells, neutron access tubes, abandoned wells, or near water sources.
- ✓ A containment area should be capable of *containing* chemicals which are mixed, drained, stored, loaded and unloaded. This includes equipment which may be present during mixing, draining, washing, storing, loading and unloading activities but which is not kept at the facility on a permanent basis.
- ✓ Washdown all on-site equipment on a rinse pad.
- ✓ Store the liquid from the rinse pad in an above-ground tank.
- ✓ Collect rinsate and reuse appropriately.
- ✓ Segregate rinsate by crop type and by chemical type to facilitate reuse.
- ✓ Rinse all equipment upon return from the field.

Disposal of Pesticides

- ✓ Rinsate or spill materials that can not be reused must be disposed of in accordance with state and federal regulations.
- ✓ Active as well as inert ingredients must be disposed of properly.
- ✓ Read and follow all label directions.
- ✓ Following proper agricultural chemical disposal procedures will lessen the potential of these chemicals to contaminate ground water.

Agricultural Chemical Spills and Accidents

- ✓ Have a facility contingency plan for procedures to be followed in the event of a fire or catastrophic event. Give the local fire department a copy of your plan.

- ✓ Clearly label exits and emergency equipment.
- ✓ Educate employees on the plan and prepare them for any emergencies.
- ✓ In the event of a spill, emergency response actions must be implemented immediately.
- ✓ Contain the spill as soon as possible.
- ✓ Notification to the proper agencies, clean-up and remediation procedures should be implemented promptly.

Cited References

Alberta Agriculture. 1988. Guide to crop production in Alberta, part 2-non-chemical control of weeds, insects, and diseases. Edmonton, Alberta, Canada.

Brach, John. n.d. Agriculture and water quality: best management practices for Minnesota. Minnesota Pollution Control Agency, Division of Water Quality, St. Paul, MN.

Brown, Paul L. and Gregg Carlson. 1990. Grain yields related to stored soil water and growing season rainfall. Montana Agricultural Experiment Station Special Report 35. Montana Agricultural Experiment Station, Montana State University, Bozeman, MT.

DeLuca, Tom and Phil Johnson. 1990. RAVE: Relative Aquifer Vulnerability Evaluation. Montana Department of Agriculture Technical Bulletin 90-01. Montana Department of Agriculture, Agricultural Sciences Division, Helena, MT.

Jacobsen, Jeffrey S. 1986. Soil sampling. Montana State University Montguide 8602AG. Montana State University Extension Service, Montana State University, Bozeman, MT.

Jacobsen, Jeffrey S. and Gregory D. Johnson. 1991. Water quality and agrichemicals in Montana. Montana State University Extension Bulletin 51. Reprint. Montana State University Extension Service, Montana State University, Bozeman, MT.

Jacobsen, J.S., T.G. Moore, and J.W. Bauder. 1986. Soil testing laboratories - a summary of services available to Montana farmers. Montana State University Extension Bulletin 1349. Montana State University Extension Service, Montana State University, Bozeman, MT.

Kammel, David W., Ronald T. Noyes, Gerald L. Riskowski, and Vernon L. Hofman. 1991. Designing facilities for pesticides and fertilizer containment. Midwest Plan Service, Agricultural and Biosystems Engineering Department, University of Iowa, Ames, IA.

Kaufman, Christine and Nancy Matheson. 1990. Protecting groundwater from agricultural chemicals: alternative farming strategies for northwest producers. 2nd ed. Alternative Energy Resources Organization, Helena, MT.

Lichthardt, Juanita and Jeffrey Jacobsen. 1992. Fertilizer guidelines for Montana. Montana State University Extension Bulletin 104. Montana State University Extension Service, Montana State University, Bozeman, MT.

Olkowski, William and Helga and Sheila Daar. 1988. What is IPM? Common sense pest control. The IPM Practitioner. Vol IV. No 3. Bio-Integral Research Center (BIRC), Berkeley, CA.

Science Application International Corporation. 1988. The small quantity generator's handbook for managing RCRA wastes - pesticide application. Revised 1991. Prepared for the Montana Department of Health and Environmental Sciences. Science Applications International Corp., Bellevue, WA.

Tennessee Valley Authority. 1991. Environmental Handbook for fertilizer and agrichemical dealers. Tennessee Valley Authority Publication Z-303. Tennessee Valley Authority Technical Library, Muscle Shoals, AL.

Thomas, Jack and Kit Sutherland, coordinators. 1990. State of Montana nonpoint source management plan. Bernie Kuntz, ed. Montana Department of Health and Environmental Sciences, Water Quality Bureau, Helena, MT.

University of Wisconsin and Wisconsin Department of Agriculture. 1989. Nutrient and pesticide best management practices for Wisconsin farms. University of Wisconsin Extension publication A-3466. University of Wisconsin Extension office, University of Wisconsin, Madison, WI.

Chapter 8

Montana Agricultural Chemical Ground Water Protection Act and Related Laws

The Montana Agricultural Chemical Ground Water Protection Act (MACGWPA)

The **Montana Agricultural Chemical Ground Water Protection Act (MACGWPA)** (80-15-101-414, MCA) gives the MDA the responsibility to develop agricultural chemical ground water management plans to prevent ground water impairment from agricultural chemicals, and protect present and future beneficial uses of ground water. Included in these plans are BMPs and educational programs. Under this act, the MDHES is responsible for adopting ground water quality standards for agricultural chemicals in ground water and classification of ground water. Joint responsibility is shared in monitoring, cleanup, quality control procedures, emergency procedures, and administrative civil penalties.

General Management Plan (GMP)

The MDA is responsible for developing and implementing a *general state agricultural chemical ground water management plan (GMP)*. The plan will include general program elements as indicated in the MACGWPA, BMPs, and best management practices. The MDHES - Water Quality Bureau is allowed a 30-day review period to prepare and submit comments on the management plan.

The *MACGWPA* designated the MDA as the agency responsible for the development of the general and specific agricultural chemical ground water management plans, and/or adoption of appropriate rules to ensure compliance with the requirements of those plans. The *MACGWPA Administrative Rules of Montana* provide the authority for the development and implementation of the general (GMP) and specific management plans (SMPs) and provides the authority to enforce specific management plans.

The *Pesticides and Ground Water Strategy* (Figure 8.1) was developed by EPA to create an opportunity for Montana (and other states) to manage the use of agricultural chemicals. EPA has requested states to develop a *generic state management plan (GSMP)* that will serve as a template for development of *pesticide specific management plans (PSMP's)* for those pesticides that will require a PSMP for continued use in that state. Montana's GMP will be equivalent to EPA's GSMP.

Statewide monitoring is mandated by 80-15-202, MCA of the *MACGWPA*. Statewide monitoring will assess the occurrence, extent and probability of agricultural chemical impairment or degradation of ground water in Montana. Results from statewide monitoring will identify particular locations where intensified monitoring is needed and may identify areas or sites where the development of a SMP will be necessary.

Specific Management Plans (SMPs)

Specific Agricultural Chemical Ground Water Management Plans (referred to as SMPs) for specific management zones (SMZs) will be developed. SMZs are areas, regions or localized sites, with boundaries defined by the MDA: where more specific or intensive management of resources is needed to protect, prevent impairment of, or minimize the presence of agricultural chemicals in ground water resources. These plans will be specific to the use of a particular agricultural chemical within defined geographic areas. All SMPs must be adopted as administrative rules and are therefore, enforceable.

Development of a SMP is based on established criteria (80-15-212(1), MCA). Any of the criteria (see below) can trigger the development and implementation of a SMP. When one or more SMPs are required at any one time, the department will prioritize the preparation of the SMPs on the basis of the specific circumstances of each area and available resources. Criteria for prioritizing SMP development may include:

- type and extent of ground water use of the contaminated aquifer,
- properties and volume of agricultural chemicals,
- concentration(s) of agricultural chemicals,
- fate and transport mechanisms of the agricultural chemical,

- vulnerability of the ground water ro impairment,
- number of persons and/or water wells that could be reasonably impacted in the area,
- and whether other corrective approaches or options are available.

When preparing a SMP, the currenr classification of any ground water included in or affected by the plan will be used. If no classification exists, the MDA must use the highest classification of ground water until such time as the ground water is classified (80-15-213, MCA).

A SMP must include requirements such as:

- ground water use,
- value and vulnerability of ground water,
- all applicable aspects of agricultural chemical usage,
- stipulations preventing or minimizing the continued and/or additional presence of agricultural chemicals in the ground water, and
- provisions to protect the present and future beneficial use of ground water.

Additional information, elements, and provisions will be considered for incorporation into the SMP when necessary to achieve the requirements of 80-15-214(1), MCA. Such additional conrents will be contingent upon:

- the extent and nature of the problem,
- the type of agricultural chemical involved,
- soil and water analytical resulrs,
- geological and aquifer characteristics when known,
- land use patterns,

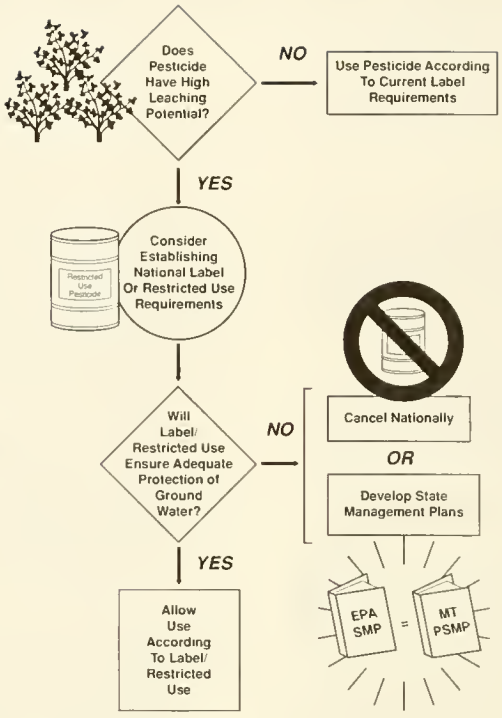


FIGURE 8.1. The USEPA will use a step-by-step process to determine the appropriate regulatory approach (i.e., national label requirements, restricted use, State Management Plans, or cancellation) for addressing a given pesticide (USEPA, 1992).

- soil types and associated charac teristics,
- meteorological conditions,
- depth to ground water,
- current and beneficial uses of the ground water,
- physiography, and
- jurisdictional and ownership boundaries.

Additional contents *may* also include (but not limited to):

- identification of areas where and agricultural chemical may be used,
- ground warer, soil, meteorological, and geological characterization,
- best management plans and practices (BMPs),
- identification of high priority ground water(s),
- certification, licensing, training, and educational requirements for agricultural chemical users,
- delineation of setback areas around water wells where activities may be restricted,
- timing, application rate, and use of agricultural chemicals,
- integrated pest management programs and alternative pest management rechniques,
- other Montana, MCA; Title 80, Chapter 8 requirements for pesticides and Chapter 10 for nutrients,
- EPA requirements, and
- integrated soil fertility practices.

SMPs may identify specific individuals or user groups within the plan. Those individuals and/or groups affected by the plan may be notified of conditions in the plan. Likewise, owners and/or users, when appropriate, may be notified when a SMP will directly affect specified areas. Any person who sells agricultural property

subject to provisions of a SMP must, when selling that property, provide the buyer with written notice about the obligations of ownership under the SMP and forward a copy of the notice to the MDA.

When developing a SMP, MDA will consider the benefits of appropriate agricultural chemical use and will consult with MSUES concerning those benefits. Additionally, users and user groups of agricultural chemicals that will be affected by the implementation of a SMP will be contacted, when feasible, to request their recommendations concerning plan development.

The MDA may also prepare and implement a commercial fertilizer ground water management plan if the MDA and the MDHES determines that residues from commercial fertilizer are present in the ground water, *or* when EPA implements a program to protect ground water from fertilizers. A commercial fertilizer ground water management plan *may* become a SMP. At this time a monitoring program for the detection and assessment of fertilizers in ground water has not been developed.

The development of a SMP must involve public participation. The MDA will first prepare an outline of the SMP for use at public meetings. This must include:

1. the facts and/or circumstances identifying the need for the SMP,
2. the MDA will sponsor interagency and public meetings and request consultation with local, state and federal agencies, universities, agricultural chemical users, and user groups for the development of the SMP,
3. the MDA will prepare the SMP draft,
4. the MDA will submit the SMP draft to MDHES for review and comment.

The MDA will then review MDHES comments and incorporate appropriate MDHES comments before the SMP draft is announced in the Montana Administrative Register, and

5. following public hearings and comment, the department will prepare the final draft of the SMP.

If the MDA finds that an emergency exists that requires immediate action to protect ground water from agricultural chemicals or to prevent use of ground water impaired or likely to be impaired by agricultural chemicals, the MDA may, without notice or hearing, issue necessary orders or adopt rules to protect public health, welfare, and safety. Duration of such an order is limited to the emergency provisions of the Montana Administrative Procedure Act as specified in 2.4.303, ARM.

Once development and implementation of an SMP has been established, the MDA in cooperation with the MDHES will govern the management of the SMP. Management of a SMP will involve the following:

- education by the MDA, university system, and other appropriate persons,
- development of specific criteria for SMP evaluation,
- initial and periodic evaluations of the SMPs,
- modification to existing SMPs when needed,
- continued monitoring of ground water,
- ensured compliance to SMP provisions through inspections and evaluations,
- issuance of compliance and emergency orders,
- enforcement of corrective measures, and
- determined appropriate penalties under noncompliance situations.

Management of a SMP will involve education of agricultural chemical users and other persons located within a specific management zone and/or affected by a SMP.

The MDA in cooperation with research, technical and interested persons, users of agricultural chemicals, members of any appointed advisory committee and the public will develop and use specific evaluation criteria for determining the effectiveness of the SMP. An initial evaluation will be performed two years after final acceptance and implementation of each SMP. Additional evaluations will be conducted as are deemed necessary. When changes to a SMP are necessary, the MDA will ensure that any changes made are in compliance with Title 80, Chapter 15, MCA.

Continued monitoring within SMZs will provide data and information on ground water quality, identification of contaminants, volumes and concentrations of agricultural chemicals, and trends and fates of agricultural chemicals in the ground warer. Monitoring will also indicate whether the provisions established for a SMP are effective in reducing the occurrence and/or concentration of agricultural chemicals in the environment. Changes within a SMZ which may affect its overall effectiveness may require a re-evaluation of monitoring site locations.

Monitoring activities and sample collection methodology will follow approved QA/QC procedures as required by MDA and/or MDHES. Monitoring results will be incorporated into the statewide

agrichemical database maintained by MDA. These results will be summarized annually and made available to the public.

Monitoring of selected sites within the area covered under the SMP will be the primary mechanism by which the success of the SMP will be measured. Monitoring will continue until a time when residue levels fall below action levels established by MDA or MDHES, or satisfy other compliance orders as allowed under 4.11.909, ARM. Responsibility for monitoring and sampling procedures will be jointly agreed to by all responsible parties.

The desired effects of a specific management plan are to prevent further impairment of ground water from a specific agricultural chemical, to identify agricultural chemical BMPs, and to educate any persons dealing with agricultural chemicals on the importance of proper storage, usage, and disposal of these chemicals.

It is unlawful for a person to violate any provision of a specific agricultural chemical ground water management plan (SMP).

The MDA may issue a compliance order to any person (whether or not that person is subject to a SMP) violating a standard, an interim numerical standard, or any other requirement established pursuant to a SMP. A compliance order may require a person to clean up any agricultural chemical that the person has accidentally or purposely dumped, spilled, misused, or unlawfully used that has a significant probability of entering ground water. Monitoring may be required to determine residue levels, trends and movement of agricultural chemicals in ground water, soils, or other materials. Characterization of ground water features such as:

- direction of flow, depth and rate of flow of ground water;
- inventory of wells, surface water features, springs, ground water recharge areas, and other ground water resources in the area;
- removal, disposal, relocation or treatment of soil or other materials;
- provision for alternative water supplies for drinking and suitable water for irrigation and other beneficial uses; and
- procedural and/or operational changes that prevent, reduce or minimize the probability of ground water impairment or degradation from agricultural chemicals.

The compliance order may require persons who are served with a compliance or emergency order to submit a written plan that describes the procedures for conducting corrective actions. The compliance order must specify the provision(s) violated and must set a time for compliance. For further details of compliance regulations and requirements refer to Title 80, Chapter 15 of the MACGWPA.

Those persons found in violation of a specific agricultural chemical ground water management plan, compliance order, or found making any false statement, representation, or certification in any record, report, other document filed is subject to administrative, judicial, and/or criminal penalties. Violation of any lawful provision of a SMP may result in a financial penalty of $100-1000 for the first offense, $500-1000 for the second offense, and $750-1000 for the third and subsequent offenses.

Compliance and Enforcement of Management Plans

The *MACGWPA* defines violations and establishes penalties that can be assessed to persons who commit violations. Authority for enforcement of this Act is the responsibility of the MDA (80-15-401, MCA). Authorized representatives of the MDA may enter public and private property to investigate, inspect and sample. Title 80, Chapter 15, MCA authorizes the investigation and inspection by representatives of the MDA of both private and public property. They may investigate conditions relating to compliance with chemical ground water management plans, monitoring requirements, ground water protection requirements, agricultural chemical labels and compliance orders. They may inspect agricultural chemicals, records, and equipment. They may also obtain samples from ground water for analysis. The MDA representatives must present credentials and can conduct such activities at reasonable times or at any time under emergency conditions. The Act provides the MDA authority to conduct the following actions during an inspection or investigation:

1. investigate conditions relating to compliance with labels, management plans, monitoring requirements, ground water protection requirements, compliance plans, and violations,
2. access and copy any records required by the Act or rules,
3. establish and inspect monitoring equipment, and
4. sample ground water and drinking water supply sources.

A compliance order can be issued to any person who causes agricultural chemicals to be present in ground water at concentrations above an established standard. Compliance orders can also be issued to require the cleanup of agricultural chemicals that have been purposely or accidentally spilled or misused where there is a significant probability that the chemical will enter ground water.

Following are actions that can be required under a compliance order:

1. monitoring residues in soil and ground water;
2. characterization of ground water features such as direction of flow, depth and rate of flow;
3. inventory of ground and surface water resources in an affected area;
4. monitoring the direction and movement of impacted ground water;
5. removal and disposal, relocation or treatment of contaminated soil or other materials;
6. provision of alternate water supplies for beneficial uses such as drinking and irrigation;
7. removal of chemicals from ground water using appropriate technology such as charcoal filtration or other methods;
8. operational changes to prevent or minimize further introduction of agricultural chemicals into ground water; and
9. submittal of a plan that describes procedures for conducting corrective actions. This plan can include quality assurance procedures, analytical methods, detection limits, and other requirements.

Prior to issuing a compliance order, the MDA is required to consult with the MDHES, so that actions taken by the two agencies are coordinated and consistent.

The MDA can issue orders or adopt rules without going through a public hearing process in the event of emergencies. Such emergency actions are taken to prevent use of water that is impaired or likely to be impaired, or to act immediately to correct situations that could result in impairment of ground water. The MDA may seek court ordered injunctions against persons who are violating the Act or engaged in actions that cause agricultural chemicals to enter ground water in violation of a standard.

Civil penalties may be assessed for violations. In general, violations occur if SMPs or orders issued under the Act are not followed, or when any provision of the Act or rules are not followed. Civil penalties can be assessed administratively by the MDA, or judicially by filing complaints in district court. Administrative civil penalties can be up to $1000 for each offense with the exception that farm applicators applying fertilizers or with a pesticide permit cannot be assessed more than $500 for the first offense. Judicial civil penalties can be up to $10,000 for each occurrence of a violation. The MDA's decision to assess civil penalties will include considerations of the gravity of violations, the significance of harm that resulted, and a person's history of compliance. The MDA can also consider the effect of a civil penalty on a person's ability to stay in business, in other words, the financial impact of the fine. In order to consider financial impacts, the MDA must have bonafide financial documentation presented by the charged person. Persons who are assessed civil penalties, have the right to contest either through the administrative or judicial process.

The Act also provides for criminal penalties for violations. Intentional violations can be subject to imprisonment up to 2 years and penalties of $25,000 for each day that a violation continues.

Criminal penalties are also authorized if persons misrepresent or try to prevent the MDA from performing authorized duties, for making false statements or records, or for revealing confidential information with intent to defraud.

Montana Pesticide Act

Enforcement of the *Montana Pesticides Act* is the responsibility of the MDA (80-8-304, MCA). Authorized representatives of the MDA can enter public or private property after obtaining consent or a warrant to conduct inspections or investigations of the following:

- pesticide application equipment,
- adverse effects to humans, crops, animals, land or property caused by pesticides,
- records on the sales or use of pesticides,
- stocks of pesticides, and storage and disposal of pesticides,
- application of pesticides, and
- the environment that may have been exposed to pesticides.

MDA representatives are also authorized to collect samples of pesticide products and any portion of the environment that may have been exposed to pesticides. Environmental samples provide information on the presence of pesticide residues. This information is helpful in documenting the presence of illegal pesticide residues, determining the presence of harmful residues, and as evidence in pesticide investigations.

Samples are taken from pesticide products to assure that the actual product being sold meets what is presented on the label or advertisement. If sample results show that the product being sold is in violation of claims, the MDA can embargo the product. Embargoed products cannot be sold and must be detained until the violation is corrected or the products are returned to manufacturers. Embargo notices can also be placed on pesticides that are not registered with the MDA or EPA, or are not properly labeled.

MDA representatives conduct routine inspections of pesticide applicators and dealers on a regular schedule. Investigations are conducted whenever violations are found during routine inspections, or when violations or pesticide incidents and damage are reported to the MDA. Section 80-8-301, MCA describes the specific report that can be filed by persons who suffer loss or damage from pesticides. Upon receipt of a verified report of loss or damage, the MDA can initiate proceedings to revoke the pesticide license of the person responsible for causing the damage. The MDA may also choose to investigate the matter further under investigative authority described above.

The *Montana Pesticides Act* allows the MDA to issue compliance orders. These can be issued to any person who has committed a violation of the Act. Orders can also be issued requiring the clean up of any pesticide that has been accidentally or purposely spilled, dumped, misused, or unlawfully used. The requirements that can be set forth in a compliance order are similar to those allowed by the MACGWPA including removal of contaminated soil and monitoring of pesticides in water, soil and other materials.

The MDA may initiate civil action in district court to seek injunctions against persons who are about to violate or are violating the Act. Injunctions are sought to prohibit a violation from occurring or from continuing.

Persons who violate the Montana Pesticides Act can be subject to misdemeanor fines or civil penalties. Misdemeanor fines can be up to $1500 per violation. Civil penalties which are issued administrarively by the MDA can be up to $1000 for each offense with the exception that farm applicators possessing a permit cannot be assessed more than $200 for the first offense. In assessing civil penalties, the MDA will consider the effect on a person's ability to stay in business, the degree of care exercised by the offender, whether significant harm resulted, and the gravity of the violation. Anyone who is assessed a civil penalty has the opportunity to request a hearing pursuant to the Montana Administrative Procedures Act.

As in the ground water act, the MDA is not required to assess the maximum penalty just because it is authorized to do so by the Act. If circumstances warrant, other enforcement actions such as Notices of Violation are issued.

Federal Insecticide, Fungicide and Rodencticide Act (FIFRA)

FIFRA authorizes civil penalties against pesticide registrants, dealers, applicators, and others. For any person other than a private applicator, the maximum civil penalty is $5000 per offense. Private applicators can be assessed a maximum of $1000 per offense.

Criminal penalties can be assessed under FIFRA for knowingly committing violations. Criminal penalties for commercial applicators are $25,000 per offense and/or one year in prison, and for registrants, the penalty is $50,000 and/or one year in prison.

In many respects, this federal act is similar to the *Montana Pesticides Act* in its regulations governing pesticide use, sale and the qualifications of persons using pesticides. Major differences exist in areas of pesticide registration requirements and regulations over the production of pesticides. Generally, administration of FIFRA is the responsibility of the USEPA. However, Section 26 of FIFRA says that States and Tribes shall have primary enforcement responsibility for FIFRA if they have the enforcement capabilities and a Plan for enforcement approved by the administrator of EPA.

Since 1979 Montana has entered into an agreement with the USEPA for enforcement of FIFRA. Under this agreement, Montana conducts inspections and investigations to assure that FIFRA is being complied with in Montana. When cases of noncompliance are found, enforcement actions are often pursued under enforcement authority of the Montana Pesticides Act because it is so similar in its requirements to FIFRA. If noncompliance is found in areas that are solely covered by FIFRA, the marter is referred to the EPA for enforcement action.

Pesticide Specific Management Plans (PSMP)

Pursuant to FIFRA Sections 3 and 6, EPA has the authority to place use restrictions on or propose cancellation of pesticides. Where national prohibition of pesticide use is not necessary and management of the pesticide is deemed necessary, EPA may require a PSMP to be developed by individual states wishing to continue use of that pesticide within that state.

EPA terminology differs from that which Montana uses. The state of Montana differentiates between a specific management plan directed at protecting SMZs which require more intensive

management (referred to as a SMP) and a pesticide specific management plan (referred to as a PSMP). EPA can designate or target a particular chemical (which is in the Federal Register) and specify that use of that chemical can only be continued if a PSMP is prepared and submitted to EPA. Both SMPs and PSMPs must be adopted as MACGWPA administrative rules and are therefore enforceable, ***but only*** PSMPs require approval by EPA.

The MDA is responsible for developing and implementing a specific agricultural chemical ground water management plan to a defined geographical area when the criteria that would trigger the plan are met. These criteria are listed in 80-15-212 MCA. Components to be included in the specific ground water management plan are listed in 80-15-214 MCA.

If Montana wishes to develop and implement a PSMP it must first notify EPA of its intent. The notification must specify the agricultural chemical targeted and must include the proposed time frame for completion of the PSMP. The PSMP review process takes 120 days to complete. If Montana wishes to continue use of agricultural chemicals that EPA proposes to institute use restrictions or cancellation of, they must submit a PSMP for approval at least 120 days prior to the EPA deadline. Submission of a PSMP will be accepted after the EPA deadline, ***but*** the sale or use of the specified agricultural chemical during any lapse period occurring between final approval of a PSMP and the EPA deadline date would be prohibited. PSMPs must have a statement that defines and describes the ground water resources to be protected and the degree of protection to be achieved under the PSMP. PSMPs must also have a stated goal of protection efforts. Protection, prevention, monitoring, and response plans should be clearly outlined and consistent with the GMPs and GSMPs ground water protection philosophy. PSMPs must identify general management measures that:

- control sources of direct pesticide impairment of ground water,
- limit the use of pesticides,
- reduce the potential for pesticide leaching to ground water, and
- reduce the quantity, toxicity, or persistence of registered pesticides (Table 8.1).

Preventative measures may include regulatory and non-regulatory approaches.

Cooperation within and between agencies and departments is essential when developing a PSMP for four reasons:

1. to assure that all relevant aspects of a PSMP are adequately addressed;
2. to develop PSMPs in a way that maintains consistency between the PSMP and other state water programs. In particular, consultation and coordination with the Soil Conservation Service is required and should be acknowledged in the PSMP. Disputes or disagreements between agencies or departments will be evaluated by USDA and if necessary by EPA;
3. to integrate all ground water protection programs within the state to avoid duplication of efforts and provide a coordinated approach to ground water protection; and
4. to maintain consistency with the USDA Conservation Compliance Plans under the Food Security Act of 1985. Discussion of relevant intrastate multi-jurisdictional coordination should also be addressed. The regional ground water coordinating committee will review PSMPs to ensure consistency between the PSMP and the other state-implemented water programs.

Components of the GMP, GSMP, SMPs, and PSMPs are discussed under GMP development. PSMPs will detail the specific technical and administrative tasks to be performed by each participating state agency. The extent to which each component must be addressed will depend on the distinctive qualities of Montana's ground water, ground water vulnerability, degree of pesticide use, agronomic practices, use and value of its ground water, and the magnitude of the perceived threat. Detailed descriptions of how each approach and activity fits into the plan along with citation of data and information sources must be included. Methodologies, monitoring, and response mechanisms used in the development of a PSMP must be outlined. To fully address the 12 required components (Chapter 1) of a PSMP, states will use information gathered from the following categories:

- **Pesticides**: product information on specific pesticides and their use within the state. Pesticide and pesticide use profiles should include the following: data sources on particular pesticides, geographic use, application rates, timing and methodologies, *OR* method and timetable being used to collect such data.
- **Hydrogeology**: assessment of the potential risk to state ground water resources including aquifer sensitivity and ground water vulnerability characrerization.
- **Water Quality**: establishment of reference points and/or MCLs (maximum contaminant levels), development of health

advisories, and determination of water quality standards.

- **Public Health and Ecosystems:** information collection concerning the risks posed to human health and the impacts on ecosystems from pesticide exposure.

- **Fate and Transport Information and Models:** prevention information and activities that define pesticide quantities and characterize pesticide occurrence and movement which impact the occurrence, movement and quality of ground water resources.

- **Agricultural Practices:** agricultural practices that impact pesticide fate and transport and its impact on ground water quality.

- **Nonagricultural Use Considerations:** explanation of how data will be obtained on the extent and types of urban/nonfarm sector uses. Description of how nonagricultural use issues are addressed will be included. Nonagricultural uses include (but are not limited to) ornamental lawns and turf, ornamental shrubs and vines, golf courses, right of way maintenance, pest control for household, domestic, and institutional dwellings and industrial sites, processed nonfood products (i.e., textiles and paper), and aquatic sites (includes canals and lakes).

- **Conservation Implementation and Cost-Sharing:** information on technical assistance and programs available for implementing agricultural practices that reduce the impact of pesticides on ground water.

TABLE 8.1. Measures that protect ground water from pesticide contamination.

Measures That Control Sources of Direct Pesticide Contamination of Ground Water
Pesticide Handling, Storage, and Disposal
Proper Well Construction and Abandonment
Measures That Reduce the Potential for Pesticide Leaching to Ground Water
Use Restrictions
Selection of Pesticides Having Low Leaching Potential
Irrigation Practices
Timing of Pesticide Applications
Measures That Limit the Use of Pesticides
Pesticides Application Limitations and Restrictions
Education and Certification Programs
Proper Well Construction and Abandonment
Geographic Setting Limitations
Measures That Reduce the Quantity, Toxicity or Persistence of Registered Pesticides
IPM Programs
Reducing Pesticide Use Through Scouting
Biological Control
Pest-Resistant Plant Varieties
Tillage Practices
Crop Rotations
Increasing Pesticide Application Efficiency

- **Alternative Technology:** technical assistance and programs on alternative agricultural practices that reduce the use of pesticides.

PSMPs address response and remediation plans. Response to confirmed agricultural chemical detections in ground water (including increases in the level of detections) will be based on a graduated approach system whereby contingency plans will outline additional preventive measures to be implemented as necessary. All components of a PSMP must be currently operational at the time of submission to EPA. When PSMPs are reviewed they will first be checked to ensure that all 12 components are included. Then each component will be reviewed for content, completeness, and adequacy of protection provided. This assures that appropriate and effective protection of ground water resources has been established and that preservation of ground water resources and associated ecosystem integrity will be maintained.

EPA will require for each PSMP developed, an End-Of-Year Grant Report and a PSMP Biennial Report. End-Of-Year Grant Reports will be used as a part of EPA's regional evaluation of state grant awards. States should, in this report, give notice of significant findings (i.e., confirmed contaminant levels above the mcl) and summarize progress of investigations and responses. Aspects of the PSMP that states are unable to implement should also be included in this report.

The PSMP Biennial Report consists of a programmatic evaluation and an environmental evaluation. The programmatic evaluation is used to determine whether a state is implementing all components of its PSMP while the environmental evaluation is used to assess the PSMPs effectiveness in preventing adverse effects to human health and the environment from pesticide impairment of ground water. EPA uses this report to evaluate a state's effectiveness in protecting its ground water resources from impairment.

Evaluation summaries will determine whether states are adequately addressing issues affecting ground water resources. When a PSMP fails to meet its objectives and goals, states will consult with the EPA regional lead office to determine if amendments to the PSMP are needed and how those amendments should be implemented. If a state fails to amend and/or implement a PSMP, pesticide usage allowed under the PSMP will be prohibited and state grant funding under the Cooperative Agreement and/or Clean Water Act Section 106 (ground water) may be withdrawn or withheld.

Remediation of Contaminated Areas

The MDA and the MDHES should be notified immediately of any positive agricultural chemical detections in ground water. Once a detection has been confirmed other wells in the vicinity of the contaminated well may be identified. Permission will be obtained to collect water samples from these wells. Sampling the other wells in the area will allow investigators to determine the depth to ground water, the regional ground water flow direction, and define the extent of the agricultural chemical impairment.

The remediation process should begin by first identifying the source of impairment. The contaminant should be contained as soon as possible to prevent widespread degradation of surface and ground water. Cleanup procedures should be implemented immediately. Preventative measures should be instituted to ensure that future impairment will not occur.

Agency Roles in Remediation of Contaminated Areas

The MDA has been given primacy by the *Montana Pesticide Act*, to investigate agricultural chemical spills. The MDHES-Water Quality Bureau has been given statutory authority by the Montana Water Quality Act (75-5-101-603, MCA) for water quality management. The MDHES-Solid and Hazardous Waste Bureau should also be notified of agricultural chemical spills. The MDHES-Solid and Hazardous Waste Bureau has the authority to regulate agricultural chemicals once they are designated as hazardous wastes.

Through the *MACGWPA* and its associated Administrative Rules and the *Montana Pesticide Act* and its associated Administrative Rules, the MDA has the authority to regulate and govern the use of pesticides in the state of Montana. The MDA is directed to protect and prevent impairment of ground water sources from agricultural chemicals. That authority allows for the control, regulation, restriction, limitation, monitoring, inspection, investigation, and enforcement activities of all agricultural chemicals used in the state. EPA and the MDHES has established the MCLs, standards, and reference points used by the State. Activities related to the prevention of impairment and/or degradation and the protection of ground water are primary goals of the Department. Responses to confirmed impairment detections in ground water or the confirmed presence of agricultural chemicals in areas which pose a threat to ground water resources are outlined in the Acts as well. The Acts constitute the basic and initial preventative and response approaches as required under the GMP and subsequent PSMP developments by EPA.

Development of PSMPs for specific agricultural chemicals that EPA intends to implement use restrictions for, or intends to cancel, requires that a management plan:

1. governs the use of the specified agricultural chemical in a manner that prevents impairment of the ground water (see SMP and PSMP development section for further details) and;
2. outlines activities to be taken in the event that initial implemented management plans fail to protect ground water and prevent impairment; and
3. in the event that agricultural chemical detections are confirmed, outlines activities and regulations to be taken including timeframes for expected implementation and responses; which initiate more aggressive activities as are necessary (which may include the exclusion of that agricultural chemical use within the state).

SMPs and PSMPs must be assessed on a case-by-case basis. A case-by-case approach allows each plan to be tailored to the individual agricultural chemical - the explicit intent of the PSMP. Actual specified activities should be identified under *each* plan.

Specific responses describing the actions to be taken, increasingly aggressive actions that can be taken, the point at which action(s) will be taken, and the time frame in which those actions should be accomplished must be specific to:

- the agricultural chemical for which the PSMP is being developed;
- status and effectiveness of current management plans, whether it be the GMP, GSMP, SMP, or PSMP;
- the prevailing agronomic practices and crops;
- use patterns (i.e., timing of application and rate of application);
- ecological sensitivity of the area(s) where applications are made;

- environmental conditions of each area (i.e., soils and climatic conditions);
- ground water characterization (confined, unconfined, natural state or condition, depth from surface, hydrogeologic considerations), vulnerability, and sensitivity; and
- other relevant considerations.

Therefore, remediation cannot be prescribed on a general basis, but must encompass the individual needs and requirements of each situation and agricultural chemical. Likewise, identification of agencies that may need to be involved in the development, implementation, and monitoring of SMPs and PSMPs (beyond the designated responsible parties listed in the GMP), will be specific to each case dependent upon the particular aspects of each situation. Additionally, involvement may evolve from an initial inclusion of other relevant agencies addressing issues specific to each plan (i.e., MDFWP, BLM, BIA, USGS, DNRC, etc.).

Remediation of contaminated areas will be addressed through administrative, technical, and enforcement activities. Division of responsibility areas will ensure that activities are assigned to and completed by the appropriate entity. Cooperation and coordination of divisional activities will ensure that each component of the plan is complete and adequate to protect Montana resources.

Treatment Methods

Treatment of water depends on the chemical properties of the agricultural chemical contaminants. Methods for treating contaminated water include removal and reuse, reverse osmosis, pump and treat, aeration, adsorption, bioremediation or a combination of these treatments.

Removal and reuse is the process of removing soil or water contaminated with agricultural chemicals from a spill site and reusing these materials. If the contaminated soil or water can not be reused, it must be disposed of properly.

Osmosis is a spontaneous process in which water with a lower total dissolved solids concentration will pass through a semipermeable membrane into a solution containing a higher concentration of dissolved solids. Flow continues until a state of equilibrium is reached. Reverse osmosis is the process of changing pressure equilibrium by applying pump pressure to a concentrated solution, flow is thus reversed across the permeable membrane. Contaminated water is fed into one end of the system. It flows through the membrane configuration and the clean water comes out of one pipe while the wastewater comes out of another. If the wastewater can not be reused it must be disposed of properly.

Pump and treat is a method whereby contaminated water is pumped out of recovery wells and treated. The contaminant is removed and the clean water is pumped back into a body of surface water or used to recharge the aquifer.

Aeration (air stripping) is a process that mixes contaminated water with air in a special chamber. The chamber is filled with beds of packing material that disperse the water to promote contact with the air. Water is introduced into the top of the chamber and trickles downward through the beds of packing material. Air is passed upward through the chamber at the same time, removing the contaminant from the water. Contaminant removal is dependent on the length of contact time, ratio of air to water, temperature, vapor pressure, and the solubility of the contaminant.

Adsorption is the process by which molecules of a contaminant collect on and adhere to the surface of an adsorbent solid. Granular activated carbon has the ability to remove a variety of compounds from water. Low solubility compounds are adsorbed better than high solubility compounds. Nitrogen compounds can be ionic and therefore, can be adsorbed. The complex molecular structure of pesticides also promotes high adsorption.

Bioremediation is a process that uses the natural contaminant-degradation capacity of microorganisms. Bacteria either feed directly on an organic contaminant, degrade it in conjunction with another primary source of carbon, or secrete enzymes to break it down. Combining treatments such as aeration and adsorption have made contaminant removal more effective.

Many home water treatment systems are available to remove pesticides, nutrients and other contaminants from drinking water. The need for and type of water treatment system required is dependant upon the particular contaminant(s) and a test of the water supply. This should be determined on an individual basis by sampling the water regularly. More detailed information can be found in *Montana State University's Extension Bulletin 102 "Household Drinking Water Protection and Treatment."*

Related Regulations for Pesticides and Fertilizers

Every year the demand for safe supplies of ground water increases. In an effort to protect ground water many federal and state laws have been established to regulate storage, usage and disposal of various materials. Following is an abstract of the more significant ground water laws:

Federal

The Clean Water Act's (CWA) basic mission is to restore and maintain the chemical, physical, and biological integrity of the nation's waters. EPA provides grants to states for development and implementation of state ground water protection strategies for the assessment and management of threats to ground water. Under the clean water act's nonpoint source authorities, EPA also provides financial assistance to states for nonpoint source monitoring/ assessments, planning, program development and implementation, and demonstration projects. Most CWA activities in Montana are implemented by the MDHES.

The Safe Drinking Water Act (SDWA) (SDWA-PL 93-523) is designed to ensure that public water systems provide water meeting minimum standards for protection of public health. As required by the SDWA, EPA establishes drinking water standards (Maximum Contaminant Levels) and water supply monitoring requirements for public water supplies to meet. Most SDWA program duties in Montana have been delegated to the MDHES.

The SDWA also authorizes EPA to provide resources to states to establish "Wellhead Protection Areas" for public drinking water wells. The SDWA also restricts underground injection of contaminants.

The Resource Conservation and Recovery Act (RCRA) (RCRA-PL 94-580) regulates management of waste, including pesticides, which may create a hazard. Wastes containing pesticide under RCRA are subject to extensive regulatory requirements governing storage, transportation, treatment, and disposal. Much of the RCRA program in Montana has been delegated to MDHES.

The Toxic Substances Control Act of 1976 (TSCA) (TSCA-PL 94-469) and the 1972 amendments to the Federal Insecticide, Fungicide, Rodenticide Act (FIFRA-PL 92-516) requires that inventories be kept of assorted chemicals and control their use. The TSCA is administered by the USEPA.

The following laws provide the USEPA the authority to directly protect ground water by controlling potential contaminants.

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (Superfund-PL 96-510) establishes a trust fund (SUPERFUND) and cost recovery procedures to finance government responses to releases, or threats of releases, of hazardous substances; CERCLA authorizes EPA to first seek to have the impairment addressed by the responsible parties, under EPA supervision. However, if ground water impairment results from application of pesticides in accordance with FIFRA requirements, the law does not allow EPA to recover costs from pesticide applicators or private users.

The Superfund Amendments and Reauthorization Act (SARA) was passed in 1986. It established "Right-to-Know" laws on releases to the environment. SARA encompasses CERCLA, as reauthorized, as well as emergency preparedness and community right to know provisions.

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) (FIFRA-PL 92-516) authorizes the EPA to regulate the marketing and use of pesticides in the United States. Before allowing a pesticide on the market, the agency weighs the risks of a pesticide against its benefits. Manufacturers must submit extensive data to EPA, including environmental fate data which will indicate the leaching potential of a pesticide. In response to ground water risks, EPA may: refuse to register a product; require label instructions which are protective of ground water resources; or allow use only in states with an EPA approved PSMP.

The Food, Agriculture, Conservation, and Trade Act (FACT) of 1990, requires private applicators to keep records of applications of restricted use pesticides rates by the USDA. These records must include the product name or brand; the EPA registration number of the product; the total amount applied; the location of the application; the size of the treated area; the crop, commodity, stored product, or site to which the pesticide was applied; the month, date, and year when applied; and the name and certification number of the person who applied or supervised the application of the restricted use pesticide. The records must be completed within 30 days of the application. This information can be important if you must respond quickly to an accident.

Pesticide applicator training and enforcement programs under the FIFRA have been delegated by EPA to the MDA.

State

The Montana Pesticides Act (80-8-301-306, MCA) became law in 1971 and was amended in 1991 giving the MDA the authority to register pesticides, license government and commercial applicators and dealers, permit farm applicators, and enforce pesticide regulation.

The Montana Solid Waste Management Act (75-10-201-233, MCA) became law in 1977 and was amended in 1991. Rules established in accordance with this Act authorize the Solid and Hazardous Waste Bureau to provide for proper solid waste management and disposal, including pesticides. The rules stipulate acceptable minimum management practices for solid waste disposal.

The Montana Comprehensive Environmental Cleanup and Responsibility Act (75-10-705-724, MCA) became law in 1989 and was amended in 1991. It was enacted to protect public health and the environment from the release of hazardous substances, to encourage cleanup of releases, to fund cleanups in cases of no voluntary actions. Included in this Act is the cleanup of pesticide impairment sites. The Act is administered by the Solid and Hazardous Waste Bureau.

The Montana Water Use Act (85-2-101-et seq., MCA) became law in 1973 and changed Montana water right laws in a number of ways including the creating of closed ground water areas and a permit and reservation system. Under the reservation system, water may be reserved for beneficial uses including minimum stream flows and/or water quality purposes. The DNRC and the Montana Water Court manage the provisions of the Act.

The Montana Water Quality Act (MWQA) (75-5-101; et seq, MCA) was passed in 1967 and amended in 1991. It provides for classification of ground and surface water, establishes water quality standards for ground and surface water, and provides for a permit program to regulate discharge of pollutants into State waters. The MDHES manage the provisions of this Act.

The Montana Board of Water Well Contractors (37-43-101-402, MCA) was established in 1961 and amended in 1991 to protect ground water by establishing standards for water well drilling and licensing of drillers. The Board is responsible administratively to the DNRC.

The Montana Ground Water Assessment Act (85-2-901-907, MCA) became law in 1991 and was enacted to provide a means to characterize the state's ground water volume, quality, and flow patterns. This is a ground water characterization and monitoring program funded by a state special revenue fund. The MBMG is responsible for carrying out the provisions of this Act.

The Montana Hazardous Waste and Underground Storage Tank Act (75-10-401-451, MCA) became law in 1981 and was amended in 1991. It established a program for proper handling and disposal of hazardous wastes. Under certain circumstances, agricultural pesticide residues, rinse waters, empty containers, cancelled or contaminated formulations, and spill cleanup residues could be defined as hazardous wastes. The Solid and Hazardous Waste Bureau (SHWB) of MDHES has adopted Administrative Rules of Montana, Title 16, Chapter 44 to manage these wastes.

Cited References

Montana Department of Agriculture. 1991. Montana agricultural chemical ground water protection act. Enacted 1989, amended 1991. Montana Department of Agriculture, Helena, MT.

Montana Department of Agriculture. 1991. Montana agricultural chemical ground water protection act: administrative rules of Montana. Enacted 1989, amended 1991. Montana Department of Agriculture, Helena, MT.

Montana Department of Agriculture. 1991. Montana pesticide act. Montana Department of Agriculture, Agricultural and Biological Sciences Division, Helena, MT.

Montana Department of Agriculture. 1991. Montana pesticide act: administrative rules of Montana. Montana Department of Agriculture, Agricultural and Biological Sciences Division, Helena, MT.

Montana, State of. 1988. Administrative rules of Montana. Title 2.4.303. State of Montana, Helena, MT.

Montana, State of. 1991. Montana codes annotated. Title 80-15-202. State of Montana, Helena, MT.

United States Environmental Protection Agency. 1993. EPA will use a step-by-step process to determine the appropriate regulatory approach for addressing a given pesticide. Figure. Unpublished. United States Environmental Protection Agency, Helena, MT.

United States Environmental Protection Agency, Office of Pesticide Programs. July 1992. Pesticide state management plan guidance for ground water protection. United States Environmental Protection Agency, Office of Pesticide Programs, United States Government Printing Office, Washington, D.C.

United States Environmental Protection Agency, Office of Pesticide Programs. July 1992. Appendix B: assessment, prevention, monitoring, and response components of pesticide state management plans. *In:* Pesticides state management plan guidance for ground water protection: implementation document for the pesticides and ground water strategy. Draft. United States Environmental Protection Agency, Office of Pesticide Programs, United States Government Printing Office, Washington, D.C.

Vogel, Michael. 1991. Household drinking water protection and treatment. Montana State University Extension Bulletin 102. Montana State University Extension Service, Montana State University, Bozeman, MT.

Chapter 9
Roles of Agencies

Agencies Involved in Education, Research, Data Collection, Compliance, and Enforcement

Numerous agencies and organizations at the federal, state, local, and nonprofit level are involved in education, research, and technical support pertaining to Montana's ground water resources. This list is not intended to be an inclusive nor a preferential listing. Sources of useful and valuable information may be available from other organizations. Descriptions of these agencies and organizations including the roles and responsibilities are presented below. Approaches include but are *not limited* to awareness, education, research, pollution prevention from point and nonpoint sources, sampling and data collection, and remediation and concern for human health.

Federal Agencies

Federal agencies such as the EPA, USGS, Soil Conservation Service (SCS), and United States Department of Agriculture-Agricultural Research Service (USDA-ARS) provide assistance, guidance, and technical information to the State for incorporation into educational programs that promote the proper use of agricultural chemicals and prevention of ground water impairment from these chemicals.

Environmental Protection Agency (EPA)

The EPA supports Montana's efforts to protect ground water from pesticides and fertilizers through two major programs. The primary sources of support are the FIFRA and CWA Programs. Technical guidance and grant funds are the means of support.

The EPA ground water strategies emphasize the need for local management of ground water resources. The variability of water resources, chemical use patterns, and vulnerability of different regions prevent a uniform national plan for ground water resource management. Broad incentives and guidelines from EPA promote local ground water management efforts. The EPA does impose appropriate nationwide restrictions upon pesticide use through product registration.

In 1984, the EPA developed the Ground Water Protection Strategy. The strategy enables EPA to provide technical and financial assistance under the CWA to states developing comprehensive ground water protection programs. Assistance is given for the development and implementation of individual state ground water management plans.

The EPA strategies are based upon common ground water protection principles. The underlying principle is the *protection* of human health and the environment. Considered are social and economic values as well as the use, value, and vulnerability of ground water resources. The principles emphasize **prevention** of ground water impairment through education and regulatory controls. Costly and technically difficult **remediation** may be necessary in the event of past impairment or failed prevention efforts. Also emphasized is the principle of **state responsibility** for ground water protection.

An important element of the EPA pesticide program is the *requirement* for a SMP. In the plan, in order for certain pesticides to be used, (such as pesticides with the greatest potential to harm ground water resources) the pesticides may be registered for use only in states with EPA approved plans.

A portion of EPA grant support, through the Water and Pesticide programs, will be provided to those states progressing toward comprehensive protection of their ground water resources.

Two technical support documents, appended to the EPA *Pesticides and Ground Water Strategy*, were developed to assist state program development efforts: Appendix A, a support document for approval and evaluation of state management plans; and Appendix B, a support document for prevention, monitoring and response. EPA Region VIII staff are actively promoting and assisting the development of Montana's program.

Various statutes provide EPA with the authority to control sources of, and to prevent ground water impairment and to pursue remediation activities concerning existing impairment of ground water resources. The EPA establishes ground water policy (direction and program consistency), coordinates federal, state and local programs, provides guidance to states on wellhead protection, and

addresses sources of impairment using a resource-based approach. Monitoring water resources for chemical and biological parameters assures that minimum health and water quality standards are met. The EPA maintains water supply data on Indian Reservations, while MDHES maintains community water supply data not maintained by EPA. Maintenance of ground water resource data is kept on STORET, the EPA's national information repository. To assure minimal chance of aquifer impairment, EPA also regulates the Underground Injection Control Program.

The EPA administers the CERCLA which is commonly referred to as the *Superfund Program*. Authorization is given for the use of federal funds under CERCLA for the restoration of water quality of severely contaminated ground water sources.

Soil Conservation Service (SCS)

The SCS develops and carries out national soil and water conservation programs in cooperation with private land owners, land users, developers, community planning agencies and other federal, state, and local agencies. The SCS provides technical and financial assistance to conservation districts and local organizations, sponsors watershed projects, resource conservation and development projects, and acts as a consultant to various agencies. The SCS is the lead agency responsible for conducting National Cooperative Soil Surveys, which provide information on soils, resource data and alternatives for land use treatments. Assistance is provided to landowners and other entities in measuring and making land-use changes as needed.

Through the Soil and Water Resources Conservation and the Food Security Acts, the SCS conducts land use inventories, cropland assessments, and wetland protection work. The agency is also responsible for River Basin Surveys/Investigations, Watershed Planning, Watershed/Flood Prevention Operations, the Great Plains Conservation Program and Agricultural Conservation Program administration.

United States Department of Agriculture - Agriculture Research Service (USDA-ARS)

The USDA-ARS administers Acts of Congress which authorize federal appropriations for agricultural research. Their mission is to promote science and technology in support of agriculture, forestry, people, and communities by the allocation of federal resources for research, encouragement of scientific development, and increasing awareness of national concerns in the natural resources.

USDA-ARS is responsible for fundamental and applied research in the protection, production, and improvement of soil, water, and air. ARS studies ways of preventing agricultural chemical impairment of ground water. These studies include research and field studies on agrichemical properties, application techniques, and chemical fate and transport mechanisms. This data is used to develop a variety of ground water models. Their Pesticide Properties Database (PPD) provides users with a compendium of chemical and physical properties of widely used pesticides. The database focuses on chemical properties impacting ground water and overall water quality.

United States Geological Survey (USGS)

The mission of the USGS, Water Resources Division, is to provide the hydrologic information needed for the optimum use and management of the Nation's water resources. This includes classifying all public lands and using scientific methodologies to determine the geologic structure and resources in the public domain. This information is published and used for the management of the Nations' energy, land, mineral, and water resources. The scope of responsibility includes appraisals of problem-oriented resources, interpretive studies, and research in the field of hydrology. The majority of the work conducted by the USGS is at the request of local, state and federal agencies.

In Montana, the USGS has collected and disseminated information on the quantity and quality of water in streams, lakes, and aquifers for more than a century. Ground water data collected from a variety of USGS projects are entered into the main USGS storage system called *WATSTORE* (Water Data Storage and Retrieval System). Information can be requested from any USGS office or the State Library in Helena, Montana. All data from WATSTORE are also entered in *STORET*. Information obtained from the data-collection programs, investigative studies, and research efforts is also available to water-resource managers, regulators, developers, and the general public through annual data reports, formal published reports, and open-file releases.

State Agencies

Montana Department of Health and Environmental Sciences (MDHES)

The Montana Water Quality Act (MWQA) (MCA 75.5.101-603) provides statutory authority to the Water Quality Bureau (WQB) of the MDHES for water quality management. The MWQA authorizes the MDHES, under the oversight of the Board of Health and Environmental Sciences, to establish water quality standards, conduct inspections, issue compliance orders, and levy civil and

criminal penalties for violations. It is a violation of the MWQA to cause pollution of state waters or to place wastes in a location where they are likely to cause pollution of state waters. The MWQA has a nondegradation policy requiring that existing water quality be maintained even if it is higher than established standards.

The MWQA authorizes MDHES to cooperate with public and private entities to plan for the prevention and control of pollution. Permits are required and issued by MDHES for discharges of pollutants to ground and surface waters. The MWQA also provides broad authority for control of nonpoint source pollution through application of "all reasonable land, soil, and water conservation practices" (ARM 16.20.1011). These practices must protect present and reasonably anticipated beneficial uses (ARM 16.20.603).

The WQB's has provided funding for agricultural chemical research projects and cooperated with other state and federal agencies conducting agricultural chemical impairment research.

The WQB acquires data for use in projects from other state and federal agencies such as the MBMG, MDA, and the USGS. Agency interaction has benefited projects including the production of a statewide map of the distribution, use, and vulnerability of ground water and the Nonpoint and Point Source Demonstration Project of Wellhead Protection For Alluvial Aquifers Within the Clarks Fork Yellowstone Valley.

The WQB is involved in educational programs regarding nonpoint source pollution abatement through the activities of the water management section, the permits/ground water section regarding wellhead protection, and the municipal water supply section regarding protection of public water supplies.

In response to public concern about Montana's ground water, the MDHES-WQB is accelerating educational programs through the Nonpoint Source (NPS) Program. The NPS Program, using grants received from the EPA, promotes agricultural BMPs.

The WQB has initiated an educational program to inform Montanans about wellhead protection. The program plan includes establishing a computer data base of information sources on wellhead protection, publishing written information, surveying public interest in wellhead protection, conducting educational presentations, public hearings on wellhead protection, and sponsoring training sessions for community volunteers.

The potential problem of agrichemicals contaminating surface water and ground water is addressed via regular training of water and wastewater operators. Staff are available to train the public in wellhead protection, the mechanisms of ground water impairment and the testing and treatment of contaminated sources. Training also includes general sessions on handling practices for herbicides around water and waste water system components (such as lagoons, hydrants, valves, etc.). The MDHES also administers the Public Water Supply Law MCA Title 75, Chapter 6. The MDHES-WQB Drinking Water Section enforces maximum contaminant levels (MCLs) in public water supplies pursuant to ARM 16.20.203-207. Included in the MCLs are acceptable levels for pesticides and nitrate in drinking water. The MDHES also administers numerous other statutes related to water quality protection and pesticides including: The Comprehensive Environmental Cleanup and Responsibility Act (Superfund), Title 75, Chapter 10, the Sanitation is Subdivisions Act, Title 76, Chapter 4 and the Hazardous Waste Management Act, Title 75, Chapter 10.

Montana Department of Natural Resources and Conservation (DNRC)

The DNRC is responsible for ensuring the wise management, development, conservation, and use of some of Montana's natural resources in a manner consistent with environmental quality. It works to sustain and improve the benefits derived from our water, soil, and rangeland; to encourage energy conservation and the use of renewable energy resources; and to make certain that energy facilities and water projects under its jurisdiction are developed with minimum adverse environmental effects. The Department directs a wide variety of programs in meeting these and related goals and objectives. The DNRC is provided for in Section 2-15-3301, MCA.

The Water Resources Division administers the Water Use Act under which permits for use of ground water and surface water are obtained. Permit applications are evaluated using criteria based on water availability, effect on other water users, and adequacy of removal. Permits may contain restrictions or limitations to protect water resources. Other ground water responsibilities include ground water management and financial and technical assistance in ground water studies.

The Oil and Gas Conservation Division, attached to the department for administrative purposes only, regulates oil and gas exploration and production activities. The division maintains well logs of exploration and production wells, and regulates locations of geophysical exploration, the plugging of shot holes, and underground injection control.

The Reserved Water Rights Compact Commission staff provides technical support essential to negotiations by the Reserved Water Rights Compact Commission, such as historical and legal research, and analysis of soils, vegetation, land use, hydrology, and analysis of economic and engineering feasibility.

The Board of Water Well Contractors, which is allocated to the

DNRC for administrative purposes only, provides technical support for drillers and for parties reporting well complaints; and provides educational activities for licensed drillers and monitoring well constructors.

Controlled ground water areas can be established under Montana Water Law by the Board of Natural Resources and Conservation. Such areas can be proposed by the DNRC, or by petition by at least 20 people or one-fourth of the users (whichever is less) of ground water in a ground water area. Basically, the criteria for establishing a controlled ground water area are oriented toward addressing problems related to excessive withdrawals of water from an aquifer. There are currently two such areas in Montana.

Montana Bureau of Mines and Geology (MBMG)

The MBMG is a nonregulatory research and public service agency located at the Montana College of Mineral Science and Technology, Butte, Montana. The MBMG administers the Ground Water Assessment Program and provides oversight and technical assistance to MDHES and EPA on several Superfund sites.

The MBMG gathers and publishes information on the geology, topography, and mineral deposits of the state, including metals, nonmetals, coal, oil, gas, and ground water. These responsibilities include the study of geologic and hydrogeologic processes in Montana. Data and information is collected through cooperative participation with other agencies. Laboratory studies conducted by the Bureau generate ground water quality data which may be used by other agencies. The MBMG functions as a ground water information depository (Ground Water Information Center, GWIC) which includes information on well logs, water quality data and drilling.

The GWIC is housed at the MBMG and is the repository for most of Montana's existing ground water data. The MBMG staff have been responsible for many ground water field investigations and have performed work under contract or in cooperation with virtually all other state and federal agencies that are responsible for ground water programs in Montana. The research, data collection, and analyses provided through the program supply an information data base that assists regulatory agencies, public and private organizations and individuals in making ground water management decisions and recommendations.

The Montana Ground Water Assessment Act established a comprehensive program at the MBMG to assess and monitor the state's ground water. The primary goal of the Ground Water Assessment Act is to improve the quality of ground water management, protection, and development decisions within the public and private sectors by systematically characterizing and monitoring the state's ground water and by improving access to ground water information. The Assessment Program includes the following components:

The Ground Water Assessment Steering Committee was established by the Legislature to guide the assessment and monitoring programs and to coordinate ground water management, protection, development, and research functions among units of State, Federal, and local government. The Steering Committee includes water agencies in State and Federal government, and representatives of local government and water-user groups.

The Ground Water Monitoring Program was designed to provide a long-term record of water quality levels for the State's major aquifers. The Ground Water Characterization Program will map the distribution and document the water quality and physical properties of individual aquifers in 21 areas, one to five counties in size.

All information generated by the Assessment Act programs will be maintained at the GWIC and distributed through the GWIC and the Natural Resources Information System (NRIS).

Montana Department of Agriculture (MDA)

The MDA administers the Montana Pesticides Act, Noxious Plant Management Act, Montana Plant Management Act, and the MACGWPA. The MDA maintains the Chemistry Station and Analytical Laboratory at MSU. The MDA encourages and promotes the interests of all agricultural and allied industrial activities in Montana.

The MDA is involved in the protection and prevention of impairment of ground water and remedial efforts where ground water is affected by or is vulnerable to impairment by agricultural products and/or processes. Authority for this work is granted under the MACGWPA. The MDA is the lead agency responsible for work carried out under this Act. Activities include conducting research, establishing monitoring programs, defining BMPs, developing GMP's and SMP's for Montana's vulnerable aquifers, regulating chemical usage, governing impairment prevention, developing remediation plans, teaching and training of initial and recertification courses for pesticide applicators, and registration of pesticides in the state. In 1984, the MDA started a statewide ground water monitoring program. In 1990, MDA established a state wide network of monitoring wells in major agricultural production areas for the detection of agricultural chemicals in ground water. Results are stored in a data base information system which can be utilized by the MDA and other agencies. The MDA is also involved in cooperative ground water studies with other agencies.

Enforcement of the MACGWPA is accomplished by inspections, environmental sampling, and enforcement of specific management plans. Routine inspections are conducted of persons who sell or use agricultural chemicals to check for compliance with label directions. MDA staff can inspect records, collect ground water samples, and monitor compliance with Department issued compliance orders and SMPs.

Compliance orders can be issued whenever a standard for agricultural chemicals in ground water has been violated or whenever an incident has occurred that creates a significant probability that agricultural chemicals will enter ground water. Compliance orders require cleanup of residues and monitoring of soils and ground water.

MDA staff also provide assistance in cases of incidents involving agricultural chemicals. Examples of incidents include spills, misuse of products, illness, and environmental damage. Such assistance can help to control incidents, assess damage, and remediate problems. Such incidents will generally be investigated to determine causative factors and possible violations of law.

Montana State University (MSU)

The MSU functions as a land grant research and educational institution providing students opportunities to learn and become proficient users and managers of environmental resources. The University offers programs through the Engineering and Earth Science programs and the Plant, Soil and Environmental Sciences Department. Ground water issues and science-based agricultural activities are addressed through course work offered as a part of student curriculums and basic and applied research programs.

Through research, MSU provides knowledge, tools and efficient methods of resource use which cause minimal disruption of and maximum protection of the environment. MSU also directs eight Agricultural Experiment Stations involved in agricultural production and research. The Agricultural Experiment Stations, located throughout the state, are representative of the various geographic, geologic, topographic, and climatic conditions found in the state of Montana. Through research at the University and the Agricultural Experiment Stations, valuable data and information is provided to agricultural users.

Montana State University Extension Service (MSUES)

The Montana State University Extension Service was established as a result of the federal Smith-Lever Act of 1914. The MSUES is headquartered at MSU in Bozeman and serves 53 of 56 Montana counties through 49 county Extension offices. The mission of the MSUES is to help people improve their lives and communities through an educational process that uses research-based knowledge in response to local, state, and national issues. Technically trained specialists conduct applied research, develop and deliver educational programs, and provide technical assistance on a variety of water quality issues. The private pesticide training program has conducted numerous training programs with ground water protection activities which includes basic information on the safe handling, application, storage, and disposal of pesticides and pesticide containers. The IPM educational program attempts to reduce pesticide applications in grain and hay production systems. A comprehensive educational program on the optimum use of nutrients and soil management practices for environmental protection, on the many soil and climatic conditions in Montana is directed through the soils program. An urban pest management program and Farm*A*Syst risk assessment program are under development. County-based faculty conduct classroom and field educational programs. The MSUES participates in the development and delivery of educational programs of the Certified Crop Advisor program.

Montana State Library (MSL)-Water Information System (WIS)

The WIS is a water data clearinghouse and referral service within the NRIS at the State Library. The Water program serves state and federal governmental agencies, business and industry, and private citizens. The System provides access to all kinds of water-related information from a variety of sources including; the USGS, USEPA, USSCS, USWS, MBMG, and others. In addition, the WIS promotes and facilitates information sharing to help prevent duplication of effort among agencies and organizations that collect, manage, or use water information. The primary objective is to assure that information collected at considerable expense is available for use to the fullest possible extent. To access the System contact WIS staff at (406) 444-5354.

Local Government Agencies

Conservation Districts (CDs)

Montana has 59 conservation districts which provide for the conservation of soil, water, and other natural resources. The districts operate within county-sized areas under the guidance and direction of a locally elected board of supervisors. Each district board establishes its priorities on local resource conditions and community needs.

Districts often act as liaison between land users and state/federal agencies to direct available resources toward local needs. Typical conservation district activities include natural resource education and information, resource assessments and conservation projects. Protection of streambeds and streambanks is administered by the conservation districts through the National Streambed and Land Preservation Act. Water pollution control, an extension of the conservation district's work on soil erosion, helps land users learn how to keep sediment, nutrients, and chemicals out of the water. Many district research management programs include ground water assessments, water reservations, irrigation scheduling, and wetland preservation and restoration.

Much of the conservation district's accomplishments are achieved through seminars, workshops, tours, and educational programs. Conservation districts both sponsor and receive grants for demonstration projects on nonpoint source pollution prevention using state-of-the-art pollution prevention techniques.

Montana Salinity Control Association (MSCA)

The Montana Salinity Control Association (MSCA) is a conservation district based program dedicated to the prevention, reclamation and education of nonpoint source pollution problems affecting Montana. The organization represents conservation districts in 33 eastern counties where salinity is a recognized nonpoint source pollution problem. Conserving and improving soil and water quality are the organization's principal goals. The MSCA works cooperatively with local, state, federal and private entities to achieve these goals.

The MSCA conducts hydrogeologic site characterizations, identifies ground water recharge areas, samples and monitors soil and water resources, conducts nonpoint source pollution prevention and reclamation demonstration projects, and makes resource management recommendations on a site specific basis. Emphasis is placed on intensive and alternative cropping systems, improving water management to prevent and reclaim nonpoint source pollution problems, and promote soil and water quality conservation. The MSCA provides educational materials for symposiums, workshops, farm tours and school courses.

Private Groups

The Alternative Energy Resources Organization and the Alliance for a Clean Rural Environment promote education and research of agricultural chemical best management practices and alternative methods for pest management.

Alternative Energy Resources Organization (AERO)

The Alternative Energy Resources Organization's mission is to encourage development of sustainable and alternative agriculture, community self-reliance, and renewable energy and conservation. AERO is a grassroots non-profit organization based in Helena, Montana. AERO, in cooperation with other agencies and organizations, provides educational materials for conferences, workshops, farm tours, slideshows, printed and taped information, and collaborates with on-farm research and demonstration of sustainable farming systems.

Alliance For A Clean Rural Environment

The Alliance for a Clean Rural Environment was formed in 1988 in response to public concern for the safety of water resources. The Alliance for a Clean Rural Environment is representative of industry efforts to encourage environmental stewardship and protection of water quality through education and public outreach. Educational emphasis is placed on the proper storage, mixing/loading, application, and disposal of crop chemicals and their containers. Building of rinsing pads and containment facilities; location and construction of wells; calibration; chemical behavior in soil and water systems; sealing of abandoned wells; clean up of spills; water testing; and water quality are additional topics of educational materials.

Sources of Information

The various state agencies (MDA, MDHES, MSUES, DNRC, and MBMG), private and commodity groups, and chemical manufacturers provide information on agricultural chemicals and their impact on the environment. Information provided includes ground water reports, maps, chemical analysis results, and notification of agricultural chemical spills.

Federal agencies also provide information and guidance concerning agricultural chemicals. Information provided includes how to properly handle agricultural chemicals, impacts on the environment from improper use of these chemicals, numerical standards, and associated health advisories for agricultural chemicals.

The GMP is intended for use by applicators, dealers, distributors, formulators, educational institutions, water users, and the general public. The following agencies also provide assistance in directing interested parties to the appropriate source of information.

Federal

United States Department of Agriculture, Agricultural Research Service
United States Department of Agriculture, Soil Conservation Service
United States Environmental Protection Agency United States Geological Survey

Local

City/County//Tribal Health Departments
Conservation Districts
County Health Departments
Montana Salinity Control Association
Montana State University County Extension Offices
Soil Conservation Service Field Offices
Water Quality Districts

State

Department of Health and Environmental Sciences
Department of Natural Resources and Conservation
Montana Bureau of Mines and Geology
Montana Department of Agriculture
Montana State University
Montana State University Extension Service
Montana Water Information System, NRIS, State Library
National Agricultural Library
United States Department of Agriculture, Soil Conservation Service
University of Montana

Non-profit

Alternative Energy Resources Organization
Alliance For A Clean Rural Environment
Montana Agricultural Business Association
Montana Farm Bureau
Montana Grain Growers
Women Involved In Farm Economics

Cited References

Montana Department of Agriculture. 1991. Montana agricultural chemical ground water protection act. Enacted 1989, amended 1991. Montana Department of Agriculture, Helena, MT.

Montana Department of Natural Resources and Conservation, Conservation Districts Bureau. 1992. Information Provided By Steve Schmitz. Department of Natural Resources and Conservation, Conservation Districts, Helena, MT.

Montana, State of. 1988. Administrative rules of Montana. Title 16.20.603. State of Montana, Helena, MT.

Montana, State of. 1990. Administrative rules of Montana, State of Montana, Helena, MT.

Chapter 10
If My Water Is Impaired What Do I Do?

There is a growing concern over the impairment of ground water from the use of pesticides and fertilizers. The impairment of ground water by these materials *may* affect crop productivity and the health of humans and animals.

Fertilizers and pesticides can enter ground water through both *direct* and *indirect* pathways. Direct entrance can occur from pesticide spills, through improperly or poorly constructed wells, or damaged well seals, from back siphoning as a result of spray tank filling, chemigation, or improper disposal and/or storage of pesticides and their containers. Pesticides can move through the soil and into the ground water. Mixing/loading areas, disposal sites and even normal pesticide/fertilizer applications may contribute to ground water impairment.

People may have cause for concern if family members experience persistent or sudden onset of health problems that fail to improve with medical attention. Changes in plant or crop productivity or animal health which can not be attributed to other causes and changes in the quality of drinking water may indicate that a possible water quality problem exists.

If you are concerned about the quality of your drinking water, your local county extension agent or county sanitation personnel can be contacted for assistance (see Appendix for a listing of county extension offices and county sanitarians). When agricultural chemical impairment of ground water is suspected, the MDHES and the MDA should be contacted immediately. Discontinue use of the contaminated drinking water and use an alternative source of water such as bottled water.

Changes in appearance, taste, or odor of drinking water may be caused by bacterial impairment, salinity or alkalinity problems, organic solvents, sewage, and a host of naturally occurring minerals such as iron, selenium and sulfur. If the appearance, taste, or odor of your drinking water has changed this may indicate ground water impairment. Your county extension agent or county sanitarian can suggest water treatment options that may be used to correct the quality of your drinking water.

Water samples must be collected and analyzed to determine if ground water has been contaminated. A well owner can contact the MDHES Chemistry Laboratory, MSU Analytical Laboratory, MBMG Analytical Laboratory, or any public or private laboratory for assistance in obtaining the appropriate water sample bottle; necessary chemical preservative; and instructions on how, when, and where to collect a water sample. The customer should always feel free to shop around (but cheapest is not always best). Seven important questions to ask when contacting a laboratory for water testing services:

1. Are sample bottles (containing preservatives if necessary) provided?
2. Are recommended sampling procedures provided?
3. Do they use EPA approved methods?
4. Does the laboratory provide water sample collection instructions?
5. What is the scope of analytical services provided: type(s) of tests which can be done, how will test results be reported (results should indicate whether a presence was detected and for positive detections a numerical value should be listed (i.e., 10 ppm)), will health standards or parameters be given for each analyzed constituent?
6. Will the results be interpreted and explained in a manner that is easily understandable and will recommendations be given?
7. What is turn-around time from arrival to reporting of results?

Preservation and transportation of the water sample within the designated holding time are critical to ensure sample integrity. Water sample collection instructions must be followed carefully. Analyses that could be conducted on water samples include:

- the presence of coliform and/or fecal coliform impairment,
- the concentration level of inorganics (i.e., nitrates and sulphur), and
- presence of a specific chemical or family of pesticides (i.e., phenoxy herbicides).

Fees charged for water quality analyses are dependent upon the laboratory chosen and analysis requested. The time required for test results to be completed and returned will vary from a few days

to several weeks, depending upon the laboratory chosen and the analysis requested. Testing for pesticides is more complex and more expensive than routine tests used to detect minerals and bacteria. Therefore, attempts should first be made to rule out other sources of impairment.

If agricultural chemicals are suspected as the source of ground water impairment, both the MDHES and the MDA should be contacted immediately! If the water quality analysis results indicates a well is contaminated by agricultural chemicals, the source of the impairment should be identified and contained if possible. To determine if the detection is of concern from a health standpoint, consult Table 4.3 on page 78 for MCL's and health advisory levels. Depending on the contaminant concentration level in the well water, continued use of bottled water is recommended until a treatment method is chosen and *implemented*. Connection to a public drinking water supply system (if available or accessible in the area), may be an option for some private well owners. Public drinking water supply systems undergo stringent monitoring and must meet Safe Drinking Water Standards. Another option may be to drill a new well in an area that is free from ground water impairment. In most cases the new well should be uphill from and as far from the contaminated well as possible. Technical assistance with well siting may be desirable.

The MDHES-WQB and the MDA are authorized to conduct the ground water investigations necessary to determine the cause and extent of ground water impairment. Prompt notification expedites the identification of the contaminant and development of a remediation plan to cleanup the ground water and may minimize the extent of impairment with early detection and prompt mitigation activities.

Cited References

Donovan, Joseph and Jeffrey S. Jacobsen. 1988. Iron and iron bacterial problems in Montana ground water. Montana State University Montguide MT 8804. Montana State University Extension Service, Montana State University, Bozeman, MT.

Jacobsen, Jeffrey S. and Gregory D. Johnson. 1991. Water quality and agrichemicals in Montana. Montana State University Extension Bulletin 51. Reprint. Montana State University Extension Service, Montana State University, Bozeman, MT.

Schafer, William M. 1984. Water quality testing. Montana State University Montguide MT 8418. Montana State University Extension Service, Montana State University, Bozeman, MT.

Thompson, Carol Jo. 1987. Your home water supply: is it safe? Montana State University Montguide MT 8706. Montana State University Extension Service, Montana State University, Bozeman, MT.

United States Environmental Protection Agency. 1989. Pesticides in drinking-water wells. United States Environmental Protection Agency, United States Government Printing Office, Washington, D.C.

Additional References

All references, whether cited or listed, may be obtained from the identified publisher or by contacting the Montana Department of Agriculture, Agriculture Sciences Division, Helena, Montana 59620.

Alberta Agriculture. 1988. Guide to crop production in Alberta, part 2-non-chemical control of weeds, insects, and diseases. Edmonton, Alberta, Canada.

Bergantino, Robert N. 1992. Montana Bureau of Mines and Geology Open-file Report 246 A-D. Montana Bureau of Mines and Geology, Butte, MT.

Brach, John. n.d. Agriculture and water quality: best management practicesfor Minnesota. Minnesota Pollution Control Agency, Division of Water Quality, St. Paul, MN.

Brown, Paul L. and Gregg R. Carlson. 1990. Grain yields related to stored soil water and growing season rainfall. Agricultural Experiment Station Special Report 35. Montana Agricultural Experiment Station, Montana State University, Bozeman, MT.

California Department of Food and Agriculture, Pesticide Enforcement Branch - Compliance Assessment. 1990. Pesticide enforcement investigative sampling manual. Course Outline. California Department of Food and Agriculture, Pesticide Enforcement Branch - Compliance Assessment, Sacramento, CA.

—. 1990. Pesticide enforcement investigative sampling manual. California Agricultural Department of Food and Agriculture, Pesticide Enforcement Branch - Compliance Assessment, Sacramento, CA.

Chemical and Pharmaceutical Press. 1990. MSDS reference for crop protection chemicals 1989/90, cornbelt ed. Chemical and Pharmaceutical Press, New York, NY.

Cheng, H.H. and W.C. Koskinen. 1986. Processes and factors affecting transport of pesticides to ground water. *In*: Evaluation of pesticides in ground water. American Chemical Society, Washington, D.C.

Cohen, Stuart. 1990. What is a leacher? Groundwater Monitoring Review, pp. 72-75. Summer issue. Ground Water Publishing Co., Dublin, OH.

Cooksey, Diana. 1988. Integrated crop and pest management record keeping system instructions. Montana State University Extension Service, Montana State University, Bozeman, MT.

DeLuca, T., et al. 1989. A survey of pesticide residues in groundwater in Montana. Technical Report 89-1. Montana Department of Agriculture, Agricultural and Biological Sciences Division, Helena, MT.

Donovan, Joseph and Jeffrey S. Jacobsen. 1988. Iron and iron bacterial problems in Montana groundwater. Montana Stare University Montguide MT 8804 AG. Montana State University Extension Service, Montana State University, Bozeman, MT.

Driscoll, Fletcher G. 1986. Groundwater and wells. 2nd ed. Johnson Division Publishing, St. Paul, MN.

FARM*A*SYST Program. March 1992. Farmstead pollution prevention update. FARM*A*SYST, Madison, WI.

Fawcett, Richard S. 1990. Contamination of wells by pesticides and nitrates. Water Well Journal. Water Well Journal Publishing Co., Columbus, OH.

Ferreira, Rodger F., M.R. Cannon, and Robert E. Davis. 1987. Montana ground-water quality, national water summary 1986. United States Geological Survey Water Supply Paper 2325. United States Geological Survey, Helena, MT.

Fetter, C.W. 1988. Applied hydrogeology. 2nd ed. Macmillan Publishing Co., New York, NY.

Follett, R.F. and D.J. Walker. 1989. Groundwater quality concerns about nitrogen: nitrogen management and ground water protection. Elsevier Science Publishing Co., Amsterdam, Netherlands.

Follett, R.F. 1991. Managing nitrogen for ground water quality and farm profitability. Soil Science Society America, Madison, WI.

Freeze, R. Allan and John A. Cherry. 1979. Groundwater. Prentice-Hall Inc., Englewood Cliffs, NJ.

Groff, S.L. 1958. The ground-water situation in Montana. Montana Bureau of Mines and Geology Information Circular 26. Montana Bureau of Mines and Geology, Butte, MT.

Ground Water Information Center, (GWIC). Montana College of Mineral Science and Technology, Butte, MT.

Haggerty, Patrick and John Thorne, Ph.D., directors. n.d. Welcome member letter. Alliance For A Clean Rural Environment, Kansas City, MO.

Harksen, C.J. and Karen S. Midtlyng, compilers. June 1991. Water-resources activities of the United States Geological Survey in Montana, October 1989 through September 1991. United States Geological Survey Open-file Report 91-191. United States Geological Survey, Helena, MT.

Heath, R.C. 1983. Ground-water regions of the United States. United States Geological Survey Water Supply Paper 2242. United States Geological Survey, Helena, MT.

Jackson, G., B. Webendorfer, R. Hall, J. Crowley, and D. Keeney. 1983. Nitrate, groundwater, and livestock health. University of Wisconsin Extension publication G3217. University of Wisconsin Cooperative Extension Service, University of Wisconsin, Madison, WI.

Jacobsen, Jeffrey S. 1986. Soil sampling. Montana State University Montguide 8602AG. Montana State University Extension Service, Montana State University, Bozeman, MT.

Jacobsen, Jeffrey S. and Gregory D. Johnson. 1991. Water quality and agrichemicals in Montana. Montana State University Extension Bulletin 51. Montana State University Extension Service, Montana State University, Bozeman, MT.

Jacobsen, Jeffrey S. and James W. Bauder. 1987. Soil testing procedures, interpretation and fertilizer sources. Montana State University Montguide 8704 AG. Montana State University Extension Service, Montana State University, Bozeman, MT.

Jacobsen, J.S., T.G. Moore, and J.W. Bauder. 1986. Soil testing laboratories - a summary of services available to Montana farmers. Montana State University Extension Bulletin 1349. Montana State University Extension Service, Montana State University, Bozeman, MT.

Kammel, David W., Ronald T. Noyes, Gerald L. Riskowski, and Vernon L. Hofman. 1991. Designing facilities for pesticides and fertilizer containment. Midwest Plan Service, Agricultural and Biosystems Engineering Department, University of Iowa, Ames, IA.

Kaufmann, Christine and Nancy Matheson. 1990. Protecting ground water from agricultural chemicals: alternative farming strategies for northwest producers. 2nd ed. Alternative Energy Resources Organization, Helena, MT.

Lacey, John and Mary McKone. 1992. Movement and degradation of Tordon in northern rangeland environments. Unpublished.

Leonard, R.A. and Walter Knisel. 1988. Evaluating groundwater contamination from herbicide use. Weed Technology vol. 2:207-216. Weed Science Society of America, Champaign, IL.

Levings, J.F., Robert E. Davis, and Charles Parrett. 1985. Montana ground water resources, national water summary 1984. United States Geological Survey Water Supply Paper 2275, pp. 285-290. United States Geological Survey, Helena, MT.

Lichthardt, Juanita and Jeffrey Jacobsen. 1992. Fertilizer guidelines for Montana. Montana State University Extension Bulletin 104. Montana State University Extension Service, Montana State University, Bozeman, MT.

Liemandt, Paul M. 1992. Agricultural chemical contamination site investigation/site remediation/financing, pesticide regulatory education program. Course Outline. Michigan State University, East Lansing, MI.

Lindsay, Willard L. 1979. Chemical equilibria in soils. John Wiley & Sons, New York, NY.

Mackay, Douglas M. 1992. "Role of modeling in evaluating groundwater contamination." University of California Davis Groundwater Protection Course. University of California Davis, Davis, CA.

Martin, D.L., J.R. Gilley and R.W. Skaggs. 1991. Managing nitrogen for ground water quality and farm profitability. Soil Science Society of America, Madison, Wisconsin.

McBride, Dean, Dallas E. Peterson, and Arthur H. Lamey. 1988. Persistence and mobility of pesticides in soil and water. North Dakota State University Extension Bulletin 49. North Dakota State University Extension Service, North Dakota State University, Fargo, ND.

McKenna, D.P., S.C. Schock, E. Mehnert, S.C. Mravik, and D.A. Keefer. 1989. Agricultural chemicals in rural, private water wells in Illinois: recommendations for a statewide survey. Cooperative Ground Water Report 11. Illinois State Geological Survey and Illinois State Water Survey.

Meister Publishing Company. 1992. Farm chemicals handbook '92. Meister Publishing Co., Willoughby, OH.

Miller, Kathleen. 1993. Water movement on the land surface and in the soil. Figure. Unpublished. Montana Bureau of Mines and Geology, Butte, MT.

Montagne, Clifford, Larry Munn, Gerald Nielsen, Jack Rogers, and Harold Hunter. 1982. Soils of Montana. Montana State University Extension Bulletin 744. Montana Agricultural Experiment Station, Montana State University, Bozeman, MT.

Montana Agricultural Statistics Service. 1991. Montana agricultural statistics 1991 vol. XXVIII. State of Montana, Helena, MT.

Montana Department of Agriculture. 1991. Montana agricultural chemical ground water protection act. Enacted 1989, amended 1991. Montana Department of Agriculture, Helena, MT.

—. 1991. Montana agricultural chemical ground water protection act: administrative rules of Montana. Enacted 1989, amended 1991. Montana Department of Agriculture, Helena, MT.

—. 1991. Montana pesticide act. Montana Department of Agriculture, Agricultural and Biological Sciences Division, Helena, MT.

—. 1991. Montana pesticide act: administrative rules of Montana. Montana Department of Agriculture, Agricultural and Biological Sciences Division, Helena, MT.

—. 1993. Montana surface features map. Unpublished. Montana Department Agriculture, Helena, MT.

—. 1993. Permanent monitoring well locations map. Unpublished. Montana Department of Agriculture, Agricultural Sciences Division, Helena, MT.

—. 1971-1992. Montana commercial fertilizer report. Montana Department of Agriculture, Plant Industries Division, Helena, MT.

Montana Department of Agriculture, Laboratory Bureau. 1980. Quality assurance manual for pesticide analysis. Revised. Montana Department of Agriculture, Laboratory Bureau, Bozeman, MT.

—. 1991. Montana laboratory pesticide quality assurance project plan. Montana Department of Agriculture, Laboratory Bureau, Bozeman, MT.

—. 1992. Guidance for sampling and sample documentation for pesticide enforcement residue samples. Montana Department of Agriculture, Laboratory Bureau, Helena, MT.

Montana Department of Natural Resources and Conservation. 1986. Montana water use in 1980. Montana Department of Natural Resources and Conservation Report. Montana Department of Natural Resources and Conservation, Helena, MT.

Montana Department of Natural Resources and Conservation, Conservation Districts Bureau. 1992. Information provided by Steve Schmitz. Conservation Districts, Department of Natural Resources and Conservation, Helena, MT.

Montana Department of Natural Resources and Conservation, Water Management Bureau. 1985. Issues in ground water management: an evaluation of Montana's ground water policies and programs. Governor's Ground Water Advisory Council, Helena, MT.

Montana State Legislature. 1991. Montana water quality act: administrative rules. Title 16.20.10.1002. Enacted 1967, amended 1991. State of Montana, Helena, MT.

Montana, State of. 1988. Administrative rules of Montana. Title 2.4.303. State of Montana, Helena, MT.

—. 1988. Administrative rules of Montana. Title 16.20.60-604. State of Montana, Helena, MT.

—. 1988. Administrative rules of Montana. Title 16.20.1011. State of Montana, Helena, MT.

—. 1990. Administrative rules of Montana. State of Montana, Helena, MT.

—. 1991. Montana codes annotated. Title 80.15.202. State of Montana, Helena, MT.

National Academy of Sciences. n.d. Report from committee on techniques for assessing ground-water vulnerability. 2102 Constitution Avenue, N.W., Washington, D.C.

Olson, O.E. and D.G. Fox. n.d. Great Plains beef cow-calf handbook, livestock water quality. Cooperative Extension Service - Great Plains States, GPE-1401. North Dakota State University Cooperative Extension Service, North Dakota State University, Fargo, ND.

Olkowski, William and Helga and Sheila Daar. 1988. What is IPM? Common sense pest control. The IPM Practitioner. Vol IV. No 3. Bio-Integral Research Center (BIRC), Berkeley, CA.

Parrett, C. 1990. Montana water supply and use, national water summary. 1987 ed. United States Geological Survey Water Supply Paper 2350, pp. 337-344. United States Geological Survey, Helena, MT.

Pesticide Properties Database (PPD). Montana State Library. Helena, MT.

Portier, Ralph J., Anne L. Zoeller, and Kuniko Fujisaki. Winter 1990/1991. Bioremediation of pesticide-contaminated groundwater. Remediation vol. 1:1, unk p.

Rehwinkel, Bruce. 1992. Personal communication. Montana Fish, Wildlife and Parks, Helena, MT.

Rubright, Paul. 1991. Ground water contamination potential maps of Montana. Montana State University Montguide 9107AG. Montana State University Extension Service, Montana State University, Bozeman, MT.

Schafer, William M. 1984. Water quality testing. Montana State University Montguide MT 8418 AG. Montana State University Extension Service, Montana State University, Bozeman, MT.

Schneider, Robert F. 1985. NEIC pesticide sampling guide. United States Environmental Protection Agency, Office of Enforcement and Compliance Monitoring, National Enforcement Investigations Center, Denver, CO.

Science Applications International Corporation. 1988. The small quantity generator's handbook for managing RCRA wastes-pesticides application. Revised July 1991. Prepared for the Montana Department of Health and Environmental Sciences. Science Applications International Corp., Bellevue, WA.

Seiber, James N. 1992. Overview of the problem of pesticides in ground water: factors which influence fate processes. University of California Davis Ground Water Protection Course. University of California Davis, Davis, CA.

Solley, W.B., R.R. Pierce and H.A. Perlman. 1993. Estimated use of water in the United States in 1990: United States Geological Survey Circular 1081. United States Geological Survey.

Tennessee Valley Authority. 1991. Environmental Handbook for fertilizer and agrichemical dealers. Tennessee Valley Authority Publication Z-303. Tennessee Valley Authority Technical Library, Muscle Shoals, AL.

Thomas, Jack and Kit Sutherland, coordinators. 1990. State of Montana nonpoint source management plan. Bernie Kuntz, ed. Montana Department of Health and Environmental Sciences, Water Quality Bureau, Helena, MT.

Thompson, Carol Jo. 1987. Your home water supply: is it safe? Montana State University Montguide MT 8706 HE. Montana State University Extension Service, Montana State University, Bozeman, MT.

Tisdale, Samuel, Werner Nelson, and James Beaton. 1985. Soil fertility and fertilizers. Macmillan Publishing Co., New York, NY.

University of Nebraska. 1972. Distribution of Nitrate. University of Nebraska Extension Bulletin QRS-72. University of Nebraska Cooperative Extension Service, University of Nebraska, Lincoln, NE.

University of Wisconsin and Wisconsin Department of Agriculture. 1989. Nutrient and pesticide best management practices for Wisconsin farms. University of Wisconsin Extension Bulletin A-3466. University of Wisconsin Cooperative Extension and Wisconsin Department of Agriculture, Madison, WI.

United States Department of Agriculture, Agricultural Research Service. 1990. Pesticide property database. United States Department of Agriculture, Agricultural Research Service, Beltsville, MD.

—. 1990. United States Department of Agriculture, agricultural research service pesticide properties database. Systems Research Laboratory, Beltsville, MD.

United States Department of Agriculture, Montana Department of Natural Resources and Conservation. 1981. Average annual precipitation, Montana: based on 1941-1970 base period. United States Department of Agriculture, Helena, MT.

United States Department of Agriculture, National Agricultural Library. 1991. PEST (pesticide education, safety, and training) hypermedia database fact sheet. National Agricultural Library, Beltsville, MD.

United States Department of Agriculture, Soil Conservation Service. 1982. Assessing water quality for agriculture and domestic uses. Montana Technical Environmental Note No. 13. United States Department of Agriculture, Soil Conservation Service, Bozeman, MT.

—. 1990. Pesticide data base. United States Department of Agriculture, Beltsville, MD.

United States Environmental Protection Agency. STORET. National information repository, Montana State Library, Helena, MT.

—. 1989. Pesticides in drinking-water wells. United States Environmental Protection Agency, United States Government Printing Office, Washington, D.C.

—. 1990. EPA statement of ground water principles. Final Draft. United States Environmental Protection Agency, United States Government Printing Office, Washington, D.C.

—. July 1992. Appendix A: Review, approval, and evaluation of state management plans. *In*: Pesticides state management plan guidance for ground water protection: implementation document for the pesticides and ground water strategy. Draft. United States Environmental Protection Agency, Offices of Pesticides Programs, United States Government Printing Office, Washington, D.C.

United States Environmental Protection Agency. STORET. July 1992. Appendix B: Assessment, prevention, monitoring, and response components of pesticides state management plans. *In*: Pesticides state management plan guidance for ground water protection: implementation document for the pesticides and ground water strategy. Draft. United States Environmental Protection Agency, Offices of Pesticides Programs, United States Government Printing Office, Washington, D.C.

—. July 1992. Pesticides state management plan guidance for ground water protection: implementation document for the pesticides and ground water strategy. Draft. United States Environmental Protection Agency, Offices of Pesticides Programs, United States Government Printing Office, Washington, D.C.

United States Environmental Protection Agency. 1993. EPA will use a step-by-step process to determine the appropriate regulatory approach for addressing a given pesticide. Figure. Unpublished. United States Environmental Protection Agency, Helena, MT.

United States Environmental Protection Agency, Ground Water Task Force. 1990. State/federal relationship options paper. United States Environmental Protection Agency, United States Government Printing Office, Washington, D.C.

United States Environmental Protection Agency, Office of Underground Storage Tanks. April 1988. Cleanup of releases from petroleum USTs: selected strategies. United States Environmental Protection Agency, United States Government Printing Office, Washington, D.C.

United States Environmental Protection Agency, Office of Water. 1992. Drinking water regulations and health advisories. United States Environmental Protection Agency, Washington, D.C.

—. n.d. Health advisory summary. United States Environmental Protection Agency, Washington, D.C.

—. 1990. Progress in ground-water protection and restoration. United States Environmental Protection Agency Report 440/6-90-001. United States Environmental Protection Agency, United States Government Printing Office, Washington, D.C.

—. November 1991. Drinking water regulations and health advisories. United States Environmental Protection Agency, Washington, D.C.

United States Environmental Protection Agency, Office of Ground Water and Drinking Water. July 1992. Definition of the minimum set of data elements for ground water quality. United States Environmental Protection Agency, Washington, D.C.

United States Environmental Protection Agency, Risk Reduction Engineering Laboratory (U.S.) and Center For Environmental Research Information (U.S.), Office of Research and Development. February 1990. Guides to pollution prevention-the pesticide formulating industry. United States Environmental Protection Agency, Cincinnati, OH.

United States Geological Survey. 1993. Provisional data. Unpublished, Helena, MT.

Vogel, Michael. 1991. Household drinking water protection and treatment. Montana State University Extension Bulletin 102. Montana State University Extension Service, Montana State University, Bozeman, MT.

Wauchope, R. Don, Arthur G. Hornby, Don W. Goss, and John Bert. 1990. The SCS/ARS/CES pesticide properties data base: II using it with soils data in a screening procedure. *In:* Proceeding of the third national research conference on pesticides, November 8-9 1990. unk. p.

List of Figures and Tables

Figure 1.1: Montana land use 6

Figure 1.2: Montana's top ten counties in harvested acreages of winter wheat, spring wheat and barley 7

Figure 2.1: Water movement on the land surface and in the soil .. 8

Figure 2.2: Ground water regions of the United States 9

Figure 2.3: The State of Montana divided into three divisions characterized by certain conditions of topography, climate and geology 10

Table 2.1: Estimated withdrawals, millions gallons per day rounded to nearest 1 MGD 12

Table 2.2: Well use in Montana 13

Figure 2.4: Estimated ground water withdrawals during 1990, rounded to nearest 1 MGD 14

Figure 2.5: Montana's well use 14

Figure 3.1: Principal aquifers and subdivisions 18

Figure 3.2: Potential pathways of pesticide loss and transport ... 19

Table 3.1: Selected pesticide properties which influence leaching .. 21

Table 3.2: A list of pesticides commonly used in Montana 22

Table 3.3: The content of plant essential elements in the earth and in the soil 23

Figure 3.3: Nitrogen cycle—many transformations determine the fate of soil N 24

Figure 3.4: Phosphorus cycle—most P must be liberated from mineral and organic compounds in order to be used by plants .. 25

Figure 3.5: Potassium cycle—K released from plant residue and animal waste is readily available to plants 25

Figure 3.6: Changes in plant-available N due to the addition of organic material with high C:N ratio. After organic material is broken down, final soil nitrate level is higher than original 26

Table 3.4: Total N, P and K fertilizers sold in Montana from 1971-1991 26

Table 3.5: Average amount of NO_3-N remaining in soil (0-24") by cropping system 27

Table 3.6: Average nutrient composition of common animal manures 27

Figure 3.7: Distribution of nitrate and ammonium influenced by rate of applied N, after one growing season (127 days) under fallow. Total precipitation was 9 inches 28

Figure 3.8: Nitrate movement in a Blanchard loamy sand under potatoes 29

Table 4.1: Classification of ground water 32

Table 4.2: Classification of surface water 32

Table 4.3: Maximum Contaminant Levels (MCL) for commonly used agricultural chemicals in Montana. If a MCL has not been assigned to a particular chemical, the health advisory number has been used 33

Table 4.4: Effects of nitrate in water used by livestock 33

Figure 5.1: Locations of existing permanent monitoring sites 37

Table 6.1: SDWA and National Pesticide Survey Analytical Methods for pesticides in ground water 42

Table 6.2: Analytical methods for selected pesticides 43

Figure 7.1: A medium sized pesticide/fertilizer storage containment, mixing/loading pad 50

Figure 8.1: The USEPA will use a step-by-step process to determine the appropriate regulatory approach (i.e.; national label requirements, restricted use, State Management Plans, or cancellation) for addressing a given pesticide 60

Table 8.1: Measures that protect ground water from pesticide contamination 66

Appendices

Appendix A

Agencies - State

Leo Giacometto
Director - Montana Department of Agriculture
PO Box 200201
Helena, MT 59601-0201

Robert J. Robinson
Director
Montana Department of Health and Environmental Sciences
PO Box 200901
Helena, MT 59620-0901

Dr. Andrea L. Pagenkopf
Vice Provost for Outreach and
Director Montana State University Extension Service
Montana State University
Bozeman, MT 59717

Edward T. Ruppel
Director and State Geologist
Montana Bureau of Mines and Geology
Montana Technical School
1300 West Park
Butte, MT 59107

Mark Simonich
Director
Montana Department of Natural Resources and Conservation
PO Box 202301
Helena, MT 59620-2301

Agencies-Federal

John Wardell
Director - Montana Office
Environmental Protection Agency - Region VIII
Federal Building- Drawer 10096
301 South Park
Helena, MT 59626

Richard Gooby
State Conservationist - Soil Conservation Service
Federal Building- Room 443
10 East Babcock
Bozeman, MT 59715

Joe Moreland
District Chief - United States Geological Survey
Federal Building- Drawer 10076
Helena, MT 59626

Appendix B

State of Montana

MSU Extension Service Offices

Beaverhead County
Dillon, Montana
683-2842

Big Horn County
Hardin, Montana
665-1405

Blackfeet Reservation
Browning, Montana
338-2650

Blaine County
Chinook, Montana
357-3200 or 357-2359

Broadwater County
Townsend, Montana
266-3419

Carbon County
Joliet, Montana
962-3522

Cascade County
Great Falls, Montana
727-4643

Chouteau County
Fort Benton, Montana
622-3751

Custer County
Miles City, Montana
232-7800

Daniels County
Scobey, Montana
487-2861

Dawson County
Glendive, Montana
365-4277

Deer Lodge County
Anaconda, Montana
563-8421

Fallon-Carter County
Baker, Montana
778-2883

Fergus County
Lewistown, Montana
538-3919 or 538-7611

Flathead County
Kalispell, Montana
756-5680

Flathead Reservation
Pablo, Montana
675-2700

Fort Belknap Reservation
Harlem, Montana
353-2205

Gallatin County
Bozeman, Montana
585-1325

Garfield County
Jordan, Montana
557-2770

Glacier County
Cut Bank, Montana
873-2239

Granite County
Philipsburg, Montana
859-3771

HIll County
Havre, Montana
265-5481

Judith Basin County
Stanford, Montana
566-2210

Lake County
Ronan, Montana
676-4271

Lewis and Clark County
Helena, Montana
447-8346

Liberty County
Chester, Montana
759-5625

Lincoln County
Libby, Montana
293-7781

Madison-Jefferson Counties
Whitehall, Montana
287-3282

McCone County
Circle, Montana
485-2605

Mineral County
Superior, Montana
822-4561

Missoula County
Missoula, Montana
721-4095

Musselshell - Golden Valley Counties
Roundup, Montana
323-2704

Park County
Livingston, Montana
222-6120

Phillips County
Malta, Montana
654-2543

Pondera County
Conrad, Montana
278-7681

Powder River County
Broadus, Montana
436-2424

Powell County
Deer Lodge, Montana
846-3680

Prarie County
Terry, Montana
637-2121

Ravalli County
Hamilton, Montana
363-2044

Richland County
Sidney, Montana
482-1206

Roosevelt County
Culbertson, Montana
787-5312

Rosebud - Treasure Counties
Forsyth, Montana
356-7320

Sanders County
Thompson Falls, Montana
827-4394

Sheridan County
Plentywood, Montana
765-2310

Silver Bow County
Butte, Montana
723-8262

Stillwater County
Columbus, Montana
322-5334

Sweet Grass County
Big Timber, Montana
932-5146

Teton County
Choteau, Montana
466-2491

Toole County
Shelby, Montana
434-5351

Valley County
Glasgow, Montana
228-8221

Wibaux County
Wibaux, Montana
795-2486

Yellowstone County
Billings, Montana
256-2828

Appendix C

State of Montana

Analytical Laboratories

Chemistry Station Analytical Laboratory
McCall Hall
Montana State University
Bozeman, Montana 59717
406-994-3383

Montana Bureau of Mines and Geology
Montana College of Mineral Science and Technology
Butte, Montana 59701
406-496-4166

Montana State Department of Health and Environmental Science
Chemistry Laboratory Bureau
Cogswell Building A206
Helena, Montana 59620
406-444-3444

Appendix D

State of Montana

County Sanitarian Offices

Beaverhead County
2 South Pacific Street
Dillon, Montana 59725-2799
683-4868 (FAX 683-5776)
See Broadwater County

Big Horn County
809 North Custer
Hardin, Montana 59034
665-1005 (FAX 665-1025)

Blaine County
Courthouse, Box 576
Chinook, Montana 59523
357-3310 (FAX 357-2199)

Broadwater County
515 Broadway,
Helena, Montana 59601
475-3029 - home
266-3443 - Townsend

Carbon County
P.O. Box 466, Courthouse Annex
Red Lodge, Montana 59068
446-1694 (FAX 446-2640)

Carter County
See Fallon County

Cascade County
City-County Health Dept.
1130 17th Avenue South
Great Falls, Montana 59405
761-1190 (FAX 761-1192)

Chouteau County
Choteau County Courthouse
Fort Benton, Montana 59442

Custer County
Courthouse
Miles City, Montana 59301
232-7800 ext. 50
See Powder River

Daniels County
See Sheridan County

Dawson County
297 West Bell
Glendive, Montana 59330
365-4568 (FAX 365-5772)
(Prairie, Wibaux)

Deer Lodge County
800 South Main Street
Anaconda, Montana 59711
563-8421 ext. 230

Fallon County
Box 667
Baker, Montana 59313
778-3329 (School) or
778-3558 (Home)
(Carter, part-time)

Fergus County
712 West Main
Lewistown, Montana 59457
538-7466 (FAX 538-2185)
(Golden Valley, Judith Basin, Musselshell, Petroleum, Wheatland)

Flathead County
723 5th Avenue East
Kalispell, Montana 59901
758-5760 (FAX 758-5859)

Gallatin County
Courthouse, Room 3
Bozeman, Montana 59715
585-1460 (FAX 585-1403)

Garfield County
See Treasure County

Glacier County
P.O. Box 241
Cascade, Montana 59421
468-2573 or
873-4461
(Pondera, Teton)

Golden Valley County
See Fergus County

Granite County
859-3771 (Courthouse)
See Deer Lodge County

Hill County
County Courthouse
Havre, Montana 59501
265-5481, ext. 66
(FAX 265-5487, Sheriff)

Jefferson County
Courthouse, Box H
Boulder, Montana 59632
225-4251 or 1-800-366-4251

Judith Basin County
See Fergus County

Lake County
Lake County
Land Service Dept.
Courthouse
Polson, Montana 59860
883-6211, ext. 266
(FAX 883-6255)

Lewis and Clark County
City-county Building
316 North Park
P.O. Box 1723
Helena, Montana 59624

Liberty County
Liberty County Courthouse
Chester, Montana 59522

Lincoln County
418 Mineral Avenue
Libby, Montana 59923
293-7781, ext. 228
(FAX 293-5640)

Madison County
P.O. Box 278, Courthouse
Virginia City, Montana
59755
843-5392 (FAX 843-5517)

McCone County
See Richland County

Meagher County
5075 Jackson Creek Road
Street SW
Bozeman, Montana 59715
585-9016 (FAX 822-3381)

Mineral County
Courthouse, P.O. Box 396
Superior, Montana 59872
822-4632 (FAX 822-3381)

Missoula County
City-County Health Department
301 West Alder Street
Missoula, Montana 59802
523-4755 (FAX 523-4781)

Mussellshell County
See Fergus County

Park County
414 East Callender
Livingston, Montana 59047
222-6120, ext. 262

Petroleum County
See Fergus County

Phillips County
See Valley County

Pondera County
P.O. Box 241
Cascade, Montana 59421
278-3247 or
Mobile phone 788-1791

Pondera County Continued
809 Sunset Boulevard
Conrad, Montana 59425
278-3247 or 278-3248
(Teton, Glacier)

Powder County
See Custer County

Powell County
409 Missouri
Deer Lodge, Montana 59722
846-3680, ext. 21
See Deer Lodge County

Prarie County
See Dawson County

Ravalli County
Courthouse, Box 5019
Hamilton, Montana 59840
363-6206 (FAX 363-1833)

Richland County
221 Fifth Street, SW
Sidney, Montana 59270
482-2207
(McCone)

Roosevelt County
Courthouse Basement
Wolf Point, Montana 59201
653-1590, ext. 22
See Sheridan County

Rosebud County
Box 388
251 North 17th
Forsyth, Montana 59327

Sanders County
Courthouse, Box 519
Thompson Falls, Montana
59873

Sheridan County
Planning and Sanitation
Office
Courthouse
Plentywood, Montana 59254
765-2310 ext. 316
765-2497- Home
(Daniels, Roosevelt)

Silver Bow County
25 West Front Street
Butte, Montana 59701
723-3274 (FAX 723-7245)

Stillwater County
Courthouse, Box 111
Columbus, Montana 59019
322-5237 (Fax 322-4698)
(Sweet Grass)

Sweet Grass County
See Stillwater County

Teton County
P.O. Box 241
Cascade, Montana 59421
468-2573
(Pondera, Glacier)

Toole County
Toole County Courthouse
Shelby, Montana 59474
434-5032

Treasure County
524 North Crow Avenue
665-1156
(Garfield)

Valley County
Courthouse Annex
Glasgow, Montana 59230
228-8221 ext. 64- Glasgow
654-2521- Malta
(Phillips)

Wheatland County
See Fergus County

Yellowstone City - County
Room 309, Courthouse
P.O. Box 35033
Billings, Montana 59107
256-2757 (Fax 256-2968)

Billings Regional Office
State Department of
Health & Environmental
Science
EMC Box 108
1500 North 30th Street
Billings, Montana 59101-
0298
122-2619, 657-2294
(Fax 657-2051)

Wibaux County
See Dawson County

University System

Bozeman
Dept. of Microbiology
Montana State University
Bozeman, Montana 59717
994-5665

Missoula
Building 32
University of Montana
Missoula, Montana 59812-
1387
243-2881

Office, Superintendent of Public Instruction
Division of School Food
Services
1230 11th Avenue
Helena, Montana 59620
444-2501

U.S. Food & Drug Administration
Drawer 10035 Federal
Building
301 South Park
Helena, Montana 59626
449-5259 (FAX 449-5212)

Public Health Service - Indian Health Service

Billings
711 Central Avenue
P.O. Box 2143
Billings, Montana 59103
657-6451

St. Ignatius
P.O. Box 280
St. Ignatius, Montana 59865
745-1303

Crow Agency
Environmental Health and
Eng.
PHS Indian Hospital
P.O. Box 9
Crow Agency, Montana
59022
638-3161 (FAX 638-3200)

Browning
PHS Indian Hospital
Browning, Montana 59417
338-6168

Blackfeet Tribe
Water Resources Dept.
Browning, Montana 59417
338-7840, 338-7104

Box Elder - Rocky Boy
PHS Indian Health Center
Box Elder, Montana 59521

Harlem
PHS Indian Health Center
Harlem, Montana 59526
353-2651

Lame Deer
PHS Indian Health Center
P.O. Box 70
Lame Deer, Montana 59043
477-6203, 477-6722

Poplar - Fort Peck
PHS Indian Health Service
Indian Health Center
P.O. Box 67
Poplar, Montana 59255
768-5301, 768-3491

Acronyms

AERO Alternative Energy Resources Organization

ARM Administrative Rules of Montana

BIA Bureau of Indian Affairs

BLM Bureau of Land Management

BMP Best Management Plan/Practice

CD Conservation District

CERCLA Comprehensive Environmental Response Compensation and Liability Act

CMIS Chemical Migration in Soils

CWA Clean Water Act

DNRC Montana Department of Natural Resources and Conservation

EDRP Emergency and Disaster Response Plan

EPA Environmental Protection Agency

FARM*A*SYST Farmstead Assessment System

FIFRA Federal Insecticide, Fungicide and Rodenticide Act

GLEAMS Ground Water Loading Effects of Agricultural Management Systems

GMP General Ground Water Management Plan (State of Montana)

GPD Gallons Per Day

GSMP Generic State Ground Water Management Plan (EPA)

GWIC Ground Water Information Center

ICPM Integrated Crop and Pest Management

IPM Integrated Pest Management

K_{oc} Soil Adsorption Potential

LEACHMP Leaching Model for Pesticides

MABA Montana Agricultural Business Association

MACGWPA Montana Agricultural Chemical Ground Water Management Act

MBMG Montana Bureau of Mines and Geology

MCA Montana Code Annotated

MCL Maximum Contaminant Level

MDA Montana Department of Agriculture

MDHES Montana Department of Health and Environmental Sciences

MDFWP Montana Department of Fish Wildlife and Parks

MDL Method Detection Level

MG/L Milligrams Per Liter

MGD Million Gallons Per Day

M/L Mixing/Loading Facility

MLS Mixing/Loading and Storage Sites

MRM Multi-Residue Methods

MSCA Montana Salinity Control Association

MSDS Material Safety Data Sheet

MSL Montana State Library

MSU Montana State University

MSUES Montana State University Extension Service

MWQA Montana Water Quality Act

NPS Nonpoint Source

NRIS Natural Resources Information System

PPD Pesticide Properties Database

ppm Part Per Million

PRZM Pesticide Root Zone Model

PSMP Pesticide Specific State Management Plan (EPA)

PQL Practical Quantitation Limit

QA/QC Quality Assurance/Quality Control

QWDATA Water Quality Data Processing System

RCRA Resource Conservation and Recovery Act

S Water Solubility

SARA Superfund Amendments and Reauthorization Act (1986)

SCS Soil Conservation Service

SDWA Safe Drinking Water Act

SHWB Solid and Hazardous Waste Bureau

SMP Specific Ground Water Management Plan (State of Montana)

SMZ Specific Management Zone (State of Montana)

SWUDS State Water Use Data System

$T_{1/2}$ Pesticide Half-Life in Soil

TSCA Toxic Substances Control Act

USDA-ARS United States Department of Agriculture-Agriculture Research Service

USEPA United States Environmental Protection Agency

USGS United States Geological Survey

WATSTORE Water Data Storage and Retrieval System

WIS Water Information System

WQB Water Quality Bureau

Glossary

absorption: The act of absorbing; the act of taking in or imbibing.

adsorption: The attraction and adhesion of a layer or ions from an aqueous solution to the solid mineral surfaces with which it is in contact.

agrichemicals: Chemicals associated with agriculture, such as fertilizers and pesticides.

alluvium: Clay, sand, silt, gravel, or similar detrital material deposited by running water.

anion: Negative ion.

aquifer: A water-bearing, subsurface formation capable of yielding sufficient quantities of water to a well for a beneficial use.

aquifer sensitivity: The susceptibility of an aquifer to agricultural chemical contamination.

aquifer vulnerability: The susceptibility of an aquifer to contamination resulting from the combined effects of sensitivity of the aquifer and the land use practices.

autotroph: An organism which is capable of manufacturing its own food; organisms which are capable of synthesizing food from inorganic compounds, as all chlorophyll-containing plants.

biochemical: Relating to the interaction of living organisms with chemical reactions.

biological control: Reduction in numbers or elimination of pest organisms by interference with their ecology.

buffer zone: A neutral area separating conflicting forces.

calcareous: Of the nature of, consisting of, or containing calcium carbonate.

calcium carbonate: $CaCO_3$, the most abundant and widely distributed compound of calcium.

carrying agent: Material used to attach small quantities of materials to allow for even distribution of material over large areas.

cation: A positively charged ion.

cation exchange capacity (CEC): The sum total of exchangeable cations that a soil can adsorb, expressed in milliequivalents per 100 grams of soil, clay, or organic colloid.

colloid: A gluelike substance such as a protein whose particles (molecules or aggregates of molecules) when dispersed in a solvent remain uniformly suspended and do not form a true solution.

conduit: A natural or artificial channel through which something is conveyed.

confined aquifer: (also referred to as an artesian aquifer). A geologic formation capable of storing and transmitting water in usable quantities overlain by a less permeable or impermeable formation, confining layer, placing the aquifer under pressure.

confining layer: A geologic unit having little permeability such as clay and fine silt. Ground water moves through most confining layers, although the rate of movement is very slow.

constituent: A component or element or a unit. Example: oxygen and hydrogen are constituents of water.

contamination: The process by which a substance or material is impure or unsuitable by contact or mixture with something unclean.

degradation: The presence of an agricultural chemical in ground water at a concentration that meets or exceeds the standard as defined in 80-15-102(2), MCA.

denitrification: The process of reducing nitrates to simpler compounds (nitrites, oxides of nitrogen, ammonia) and eventually free nitrogen. It occurs especially in waterlogged soils under anaerobic conditions through the action of denitrifying bacteria.

discharge area: An area in which subsurface water, including both ground water and water in the unsaturated zone, is discharged to the land surface, to surface water, or to the atmosphere.

electrical conductivity: A measure of soil's or water's salinity.

emulsion: A colloidal system consisting of minute droplets of a liquid suspended in another liquid, as oil in water.

eolian: Borne, produced, or eroded by the wind.

eutrophication: The process by which a body of water becomes either naturally or by pollution rich in dissolved nutrients.

evapotranspiration: The combined loss of water from direct evaporation and through the use of water by vegetation (transpiration).

fixation: The chemical conversion of a substance from the gaseous state to the solid state, as in nitrogen fixation where gaseous nitrogen is fixed to soil nitrogen.

fumigant: Any substance used for disinfection by use of a vapor, smoke, or gas.

fungicide: An agent which kills or inhibits the growth of fungi.

geochemical: The chemical composition of and chemical changes in the solid matter of the earth; related to chemical and geological properties of a substance.

glacial till: Unstratified drift, deported by ice and consisting of clay, sand, gravel, and boulders intermingled.

ground water: Any water of the state occupying the voids within a geologic formation and within the zone of saturation.

half life: The amount of time required for half of something to undergo a process.

herbicide: An agent which kills or inhibits the growth of plants.

heterogeneous: Unlike, dissimilar, not uniform.

heterotroph: An organism which is incapable of manufacturing its own food; one which depends upon other organisms as sources of food, as all animals, saprophytes, and parasites.

homogeneous: Composed of parts or consisting of individuals of the same kind; of uniform composition.

humus: Dark material in the soil consisting principally of organic matter.

hydraulic conductivity: A measure of the capacity of a porous medium (aquifer) to transmit water.

hydraulic gradient: Change of head values over a distance.

hydrolysis: (1) A reaction in which water is a reacting agent. (2) A decomposition reaction in which a compound on reacting with water is split into two parts, one reacting with the H of water, the other with the OH, as in the digestion of food.

igneous: Relating to or resulting from, or suggestive of the intrusion or extrusion of magma; formed by solidification of magma.

impairment: The presence of an agricultural chemical in ground water or increase in its concentration in ground water for which its present and future beneficial use may be affected and which is contrary to 80-15-103, MCA.

inert ingredient: An ingredient which is inactive; physiologically ineffective. With regard to chemicals, an ingredient which is chemically inactive.

infiltration: The flow of water downward from the soil surface into and through upper soil layers.

inorganic end products: Non-animal or plant products resulting from the degradation or reduction of a product.

insecticide: An agent which kills or inhibits insects.

integrated pest management: Pest management strategies that integrate biological, cultural and pesticide control measures.

K_{oc}: The soil adsorption potential based on organic carbon partition coefficient.

lacustrine deposits: Of, relating to, or having formed in lakes.

leachate: A solution or product obtained by leaching.

leaching: The movement of water and soluble constituents through soils.

maximum contaminant level or MCL: The highest concentration of a contaminant allowable in a public water supply.

metamorphic: A substance which is produced by metamorphism (changed by pressure, heat, and water that results in a more compact and more highly crystalline condition).

methemoglobinemia: Sometimes called "blue baby syndrome". A condition that occurs primarily in infants as a result of nitrate ingestion and its conversion to nitrite within the gastro-intestinal tract. The nitrite is absorbed into the blood stream of the infant and interferes with transport of oxygen within the body.

microorganisms: A small, microscopic animal or plant.

mineralization: The conversion of an element from an organic combination to an inorganic form as a result of microbial decomposition.

monitoring: To watch, observe, or check for a special purpose; to keep track of, regulate, or control.

mottling (soil): Irregular soil masses of various colors often resulting from impeded drainage.

mutualism: A form of symbiosis in which two organisms of different species live in intimate association with each other to the advantage of both.

nitrate: (1) A form of nitrogen (2) A salt or ester of nitric acid, as sodium nitrate.

nitrification: The oxidative conversion of ammonia or ammonium salts to nitrates, accomplished by nitrifying bacteria.

nonpoint source: A diffuse source of agricultural chemicals resulting from activities of man over a relatively large area, the effects of which must normally be addressed or controlled by a management or conservation practice.

nutrient: A nutritious or nourishing substance; any substance which promotes growth or provides energy for physiological processes.

organic matter: Living or dead plant and animal residue.

osmosis: The passage of water through a semipermeable membrane as a result of differences in the concentrations of the solutions.

parasitism: A form of symbiosis in which two organisms live in close association with each other, the one, a parasite, depending upon the other, the hose, for some essential food factor.

ppb: Parts per billion.

ppm: Parts per million.

percolate: To move, penetrate, trickle, or seep through a permeable material.

permeability: The capacity for transmitting or allowing passage through a material.

pest: Any organism which is troublesome, disturbing, noxious, or destructive.

pesticide: A substance or a mixture of substances used to destroy or control any undesirable form of animal or plant life, as a fungicide, herbicide, rodenticide, or insecticide.

pH: A symbol for expressing the concentration of hydrogen (H+) ions or hydroxyl (OH-) ions.

photochemical: Of, relating to, or resulting from the chemical action or radiant energy and especially light.

point source: Including, but not limited to chemical mixing, loading, and storage sites and sites of agricultural chemical spills.

porosity: The volume ratio between the void (pore) spaces and the solid material (such as soil or rock).

recharge area: An area in which water infiltrates the soil surface and eventually reaches the zone of saturation.

residual: That pertaining to a residue or that left behind.

residue: That which remains after a part has been taken away; the remainder.

saline seep: Areas of recently developed salinity in non-irrigated soils that are wet some or all of the time, often with white salt crusts, where crop or grass production in reduced or eliminated.

sampling: To take of sample of or from especially to judge the quality of a substance.

saturated zone: The zone in which all voids are filled with water. The water table is the upper limit.

secondary maximum contaminant level: Established allowance levels for contaminants that affect taste, odor, color and appearance of water.

sedimentary: Of, relating to, or containing sediment; formed by or from deposits of sediment.

shallow ground water: Ground water located within close proximity to the earth's surface.

soil horizon: A layer of soil or soil material differing from adjacent soil layers.

solubility: The capacity or ease in which something can be dissolved or put into solution.

soluble: Capable of being dissolved or going into solution.

solvent: A liquid in which a substance, the solute, is dissolved.

sorption: The process of taking up and holding by either absorption or adsorption.

surface water: Water present at the earth's surface.

surfactant: An agent which lowers surface tension, as soap, bile, and certain detergents.

symbiosis: A mode of life in which two organisms of different species live in intimate association with each other. Depending on the nature of the association, the relationship is designated mutualism, commensalism, parasitism.

symbiotic: Of or pertaining to symbiosis.

taxonomic: Of or pertaining to taxonomy.

taxonomy: The science of classification; the arrangement of animals and plants into groups based on their natural relationships.

toxicity: A substance's toxic or poisonous nature.

transmissivity: The capacity of an aquifer to transmit water.

unsaturated zone: The zone where the pore spaces are not completely saturated.

vadose zone: The unsaturated zone; located above the water table.

vulnerable: The factors that determine the potential for or actual impairment of degradation of an aquifer or ground water.

volatilization: The process by which a substance to converted to the gaseous state.

water table aquifer: (also referred to as an unconfined aquifer). An aquifer having a free water surface that rises and falls in response to changes in recharge and discharge.